United States Environmental Protection Agency
Office Of Air Quality Planning And Standards
Research Triangle Park, NC 27711
EPA-452/R-02-012
November 2002
FINAL REPORT
Air

Regulatory Impact Analysis of the Proposed Reciprocating Internal Combustion Engines NESHAP

Final Report

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of the Proposed
Reciprocating Internal Combustion Engines
NESHAP

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Air Quality Strategies and Standards Division (C339-01);
Research Triangle Park, N.C. 27711

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November 2002

Disclaimer

This report is issued by the Air Quality Standards & Strategies Division of the Office of Air Quality Planning and Standards of the U.S. Environmental Protection Agency (EPA). It presents technical data on the National Emission Standard for Hazardous Air Pollutants (NESHAP)for Reciprocating Internal Combustion Engines, which is of interest to a limited number of readers. It should be read in conjunction with the Background Information Document (BID) for the NESHAP and other background material used to develop the rule, which are located in the public docket for the NESHAP proposed rulemaking. Copies of these reports and other material supporting the rule are in Docket A-95-35 at EPA's Air and Radiation Docket and Information Center, 1200 Pennsylvania Avenue, N.W.; Washington D.C. 20460. The EPA may charge a reasonable fee for copying. Copies are also available through the National Technical Information Services, 5285 Port Royal Road, Springfield, VA 22161. Federal employees, current contractors and grantees, and nonprofit organizations may obtain copies from the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, N.C. 27711; phone (919) 541-2777.

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ACRONYMS AND ABBREVIATIONS

2SLB	Two-Stroke Lean Burn
4SLB	Four-Stroke Lean Burn
4SRB	Four-Stroke Rich Burn
AIRS	Airometric Information Retrieval System
A/F	Air to fuel ratio
ASM	Annual Survey of Manufacturers
BACT	Best Available Control Technology
BCA	Benefit Cost Analysis
CAA	Clean Air Act Amendments of 1990
CD	Criteria Document
C/E	Cost Effectiveness
CH_2O	Formaldehyde
CI	Compression Ignition
CNS	Central Nervous System
CO	Carbon monoxide
CRDM	Climatological Regional Dispersion Model
CSR	Cost to Sales Ratio
DOC	Department of Commerce
EIA	Department of Energy/Energy Information Administration
EPA	Environmental Protection Agency
FACA	Federal Advisory Committee Act
HAP	Hazardous Air Pollutant
HEM	Human Exposure Model
IARC	International Agency for Research on Cancer
IC	Internal Combustion
LAER	Lowest Achievable Emission Rate
LEC	Low Emission Combustion
LDCs	Local Distribution Companies
LNG	Liquefied Natural Gas
MACT	Maximum Achievable Control Technology
MIR	Maximum Individual Risk
mmBTU	Million British Thermal Units
mmcf/d	Million cubic feet per day
MRR	monitoring, recordkeeping, and reporting
Mg	Megagram
NAAQS	National Ambient Air Quality Standard
NAICS	North American Industry Classification System
NEMS	National Energy Modeling System
NESHAP	National Emission Standard for Hazardous Air Pollutants
NGLs	Natural Gas Liquids
NSCR	Non-Selective Catalytic Reduction

NSPS	New Source Performance Standard
NOx	Nitrogen Oxide
OMB	Office of Management and Budget
OPEC	Organization of the Petroleum Economic Community
OTAG	Ozone Transport Assessment Group
PM	Particulate Matter
ppbvd	parts per billion by volume (dry)
ppmvd	parts per million by volume (dry)
PSD	Prevention of Significant Deterioration
RACT	Reasonably Available Control Technology
RFA	Regulatory Flexibility Act; also Regulatory Flexibility Analysis
RfC	Reference-dose Concentration
RIA	Regulatory Impact Analysis
RICE	Reciprocating Internal Combustion Engine
SBREFA	Small Business Regulatory Enforcement Fairness Act
SCR	Selective Catalytic Reduction
SI	Spark Ignition
SIC	Standard Industrial Classification
SO2	Sulfur Dioxide
S-R Matrix	Source Receptor Matrix
UAM-V	Urban Airshed Model - Version V
URF	Unit Risk Factor
U.S.	United States
VOC	Volatile Organic Compound
VSL	Value of a Statistical Life
VSLY	Value of a Statistical Life-Year

EXECUTIVE SUMMARY

This report summarizes the benefits and costs associated with the National Emissions Standard for Hazardous Air Pollutants (NESHAP) for the Reciprocating Internal Combustion Engines (RICE) source category. This source category includes spark ignition engines that operate generally with natural gas and compression ignition engines that operate with diesel fuel, and can be classified as two-stroke, or four-stroke engines. They are also classified by the richness of the fuel mix: rich burn or lean burn. The affected RICE units operate in a variety of markets and service industries. For instance, some are typically used along natural gas pipelines to provide adequate pressure to transmit fuel through the pipeline. Others are also used to provide power in a remote area of an operation in industries such as health services, energy generation, oil and gas extraction, and quarrying of non-metallic minerals.

The proposed NESHAP for RICE will impact existing and new sources of RICE units and is expected to reduce HAP emissions by 5,000 tons per year by the year 2005 due to controls required to achieve the MACT floor—the minimum level of control mandated by the Clean Air Act. The controls applied to RICE units will also achieve annual reductions of criteria pollutants, including: 234,400 tons of carbon monoxide (CO) per year by 2005, and 167,900 tons of nitrogen oxides (NOx) per year, and 3,700 tons of particulate matter (PM_{10}).

The total social cost of these HAP reductions is \$255 million (1998\$) in the 5th year after implementation. This cost is spread across more than 25 different manufacturing and service industries, which results in minimal changes in prices and production levels in most affected industries. However, because natural gas engines are a large portion of the controlled units, the natural gas market (including fuel usage for energy generation, as well as the extraction, processing, and transmission industries for natural gas) has a larger share of the regulatory burden associated with this rule. Natural gas prices are expected to rise by about 0.3 percent, which is greater than for other affected industries, but which is considered a modest change in comparison to historical price changes. Prices in other energy generation markets, such as oil, coal and electricity do not change substantially, although a modest amount of fuel switching from natural gas to electricity or coal is anticipated.

A screening of the impacts on firms owning RICE units was conducted for firms who own existing RICE units. In our database of approximately 26,800 existing engines, we determined that about 3,300 units could be affected by the existing source MACT. We were able to identify the ownership of 889 of these engines. Using the subset of 889 units, we determined these engines operate at 385 facilities owned by 84 parent firms. Of these firms, 13 were defined as small entities. None of these small firms are anticipated to have compliance costs associated with the existing source MACT that exceed three percent of firm revenues and only two small firms have impacts between one and three percent. The average profit margin in the primary affected industries is approximately five percent. Given that none of the small entities evaluated in our subset have impacts that exceed the five percent profit margin, and only 16 percent may have impacts greater than one percent of total revenues, we conclude that this proposed action will not have a significant impact on a substantial number of small entities.

For new sources, it can be reasonably assumed that the investment decision to purchase a new engine may be slightly altered as a result of the regulation. In fact, for the entire population of affected engines (approximately 20,000 new engines over a 5-year period), only 5 fewer engines (0.02 percent) may be purchased due to market responses to the regulation. It is not possible, however, to determine future investment decisions at the small entities in the affected industries, so we cannot link these 5 engines to any one firm (small or large). Overall, it is very unlikely that a substantial number of small firms who may consider purchasing a new engine will be significantly impacted because the decision to purchase new engines is not altered to a large extent.

Although the proposed rule will not have a significant impact on a substantial number of small entities, we nonetheless have tried to reduce the impact of this rule on small entities. In this proposed rule, we are applying the minimum level of control (i.e., the MACT floor), and the minimum level of monitoring, record keeping, and reporting to affected sources allowed by the

CAA. In addition, RICE units with capacities under 500 hp and those that operate as emergency/temporary units are not covered by the rule. This provision is expected to reduce the level of small entity impacts.

The HAPs that are reduced as a result of implementing the RICE NESHAP will produce a variety of benefits, some of which include: the reduction in the incidence of cancer to exposed populations, neurotoxicity, irritation, and crop or plant damage. The rule will also produce benefits associated with reductions in CO, PM_{10}, and NOx emissions. Human health effects associated with exposure to CO include cardiovascular system and central nervous system effects, which are directly related to reduced oxygen content of blood and which can result in modification of visual perception, hearing, motor and sensorimotor performance, vigilance, and cognitive ability. Human health effects associated with PM and NOx include respiratory problems, such as chronic bronchitis, asthma, or even death.

Although the rule will achieve reductions in HAPs, CO, PM_{10} and NOx, the benefit analysis presented in this RIA is only able to place a dollar value on the benefits associated with the health effects of PM_{10} and NOx (as it transforms into PM), and the health effects of NOx as it transforms into ozone.

We use two approaches (referred to as Base and Alternative Estimates) to provide benefits in terms of health effects and in monetary terms. While there is a substantial difference in the specific estimates, both approaches show that the RICE MACT may provide benefits to public health, whether expressed as health improvements or as economic benefits. These include prolonging lives, reducing cases of chronic bronchitis and hospital admissions, and reducing thousands of cases in other indicators of adverse health effects, such as work loss days, restricted activity days, and days with asthma attacks. In addition, there are a number of health and environmental effects which we were unable to quantify or monetize. These effects, denoted by "B" are additive to the both the Base and Alternative estimates of benefits. Also, in determining the monetary value of the effects, we use two different discount rates to provide a present value of the benefit estimates. We adopt a 3 percent discount rate to reflect reliance on a "social rate of time preference" discounting concept, as recommended by EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b). We also calculate benefits using a 7 percent discount rate consistent with an "opportunity cost of capital" concept to reflect the time value of resources directed to meet regulatory requirements, as recommended by OMB Circular A-94 (OMB, 1992). In this analysis, the benefit estimates are not significantly affected by the choice of discount rate. The Base Estimate of monetized benefits of the PM_{10} and NOx health effects in 1998 dollars are \$280 million + B (using a 3 percent discount rate), or \$265 million + B (using a 7 percent discount rate). The Alternative Estimate totals \$40 million + B (using a 3 percent discount rate), or \$45 million + B (using a 7 percent discount rate).

The Base Estimate of benefits reflects the use of peer-reviewed methodologies developed for earlier risk and benefit-cost assessments related to the Clean Air Act, such as the regulatory assessments of the Heavy Duty Diesel and Tier II Rules and the Section 812 Report to Congress. The Alternative Estimate explores important aspects of the key elements underlying estimates of the benefits of reducing NOx emissions, specifically focusing on estimation and valuation of mortality risk reduction and valuation of chronic bronchitis. The Alternative Estimate of mortality reduction relies on recent scientific studies finding an association between increased mortality and short-term exposure to particulate matter over days to weeks, while the Base Estimate relies on a recent reanalysis of earlier studies that associate long-term exposure to fine particles with increased mortality. The Alternative Estimate differs in the following ways: it explicitly omits any impact of long-term exposure on premature mortality, it uses different data on valuation and makes adjustments relating to the health status and potential longevity of the populations most likely affected by PM. It also uses a cost-of-illness method to value reductions in cases of chronic bronchitis while the Base estimate is based on individual's willingness to pay to avoid a case of chronic bronchitis.

Given the lack of approved methods to value HAPs and CO, the benefits estimates provided must be considered with all other non-monetized benefits and information on costs, economic impacts, and legal requirements to understand the full impact of the rule on society.

The tables below summarize the regulatory impacts of the RICE NESHAP, including: total social costs, economic impacts, small business impacts, quantifiable benefits, and net benefits (i.e., benefits minus costs). Approximately 90 percent of the total benefits (\$255 million under the Base Estimate, and \$35 million under the Alternative Estimate) are associated with NOx reductions from the 4SRB subcategory for new and existing engines. Approximately 10 percent of the total benefits (\$25 million under the Base Estimate, and \$5 million under the

Alternative Estimate) are associated with the PM reductions from the compression ignition engine subcategory at new sources.

Table ES-1. Summary of Regulatory Impacts of the RICE NESHAP

Summary of Social Costs (millions 1998$)[a]:	
Natural Gas Market	$ 35
Mining Sector	$ 20
Construction Sector	$ 10
Chemicals	$ 20
Energy Use Sectors:	
Commercial Sector	$ 70
Residential Sector	$ 40
Transportation Sector	$ 15
Other Industrial Sectors (23 industries)	$ 45
Total Social Costs	**$255**
Economic Impacts:	
Change in Natural Gas Prices	0.30%
Change in Prices in Other Industries	0.00% to 0.05%
Change in New Engine Purchases	0.02% (5 out of 20,000 engines)
Small Business Impacts:	
Firms with costs above 1% of revenues	2
Firms with costs above 3% of revenues	0
Total Benefits (millions 1998$)[a]:	
Base Estimate	
Using 3% Discount Rate	$280 + unquantified benefits
Using 7% Discount Rate	$265 + unquantified benefits
Alternative Estimate	
Using 3% Discount Rate	$40 + unquantified benefits
Using 7% Discount Rate	$45 + unquantified benefits

[a] Costs and benefit values are rounded to the nearest $5 million.

Table ES-2. Summary of Costs, Emission Reductions, and Quantifiable Benefits, by Engine Type

Type of Engine	Total Annualized Cost (million $/yr in 2005)	Emission Reductions[a] (tons/yr in 2005)				Quantifiable Annual Monetized Benefits[b, c] (million $/yr in 2005)	
		HAP	CO	NOx	PM	Base Estimate	Alternative Estimate
2SLB–New	$3	250	2,025	0	0	B_1	B_2
4SLB–New	$64	4,035	36,240	0	0	B_3	B_4
4SRB–Existing	$37	230	98,040	69,900	0	$105 + B_5 $100 + B_6	$15 + B_7 $15 + B_8
4SRB–New	$47	215	91,820	98,000	0	$150 + B_9 $140 + B_{10}	$20 + B_{11} $25 + B_{12}
CI–New	$96	305	6,320	0	3,700	$25 + B_{13}	$5 + B_{14}
Total	$255	5,035	234,445	167,900	3,700	$280 + B $265 + B	$40 + B $45 + B

[a] For the calculation of PM-related benefits, total NOx reductions are multiplied by the appropriate benefit per ton value presented in Table 8-7. For the calculation of ozone-related benefits, NOx reductions are multiplied by 5/12 to account for ozone season months and 0.74 to account for Eastern States in the ozone analysis. The resulting ozone-related NOx reductions are multiplied by $28 per ton. Ozone-related benefits are summed together with PM-related benefits to derive total benefits of NOx reductions. All benefits values are rounded to the nearest $5 million.

[b] Benefits of HAP and CO emission reductions are not quantified in this analysis and, therefore, are not presented in this table. The quantifiable benefits are from emission reductions of NOx and PM only. For notational purposes, unquantified benefits are represented with a "B" for monetary benefits. A detailed listing of unquantified NOx, PM, and HAP related health effects is provided in Table 8-13.

[c] Results reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).

Table ES-3. Annual Net Benefits of the RICE NESHAP in 2005

	Million 1998$[a]
Social Costs[b]	$255
Social Benefits[b, c, d]:	
HAP-related benefits	Not monetized
CO-related benefits	Not monetized
Ozone- and PM-related welfare benefits	Not monetized
Ozone- and PM-related health benefits:	
Base Estimate	
–Using 3% Discount Rate	$280 + B
–Using 7% Discount Rate	$265 + B
Alternative Estimate	
–Using 3% Discount Rate	$40 + B
–Using 7% Discount Rate	$45 + B
Net Benefits (Benefits - Costs)[c, d]:	
Base Estimate	
–Using 3% Discount Rate	$25 + B
–Using 7% Discount Rate	$10 + B
Alternative Estimate	
–Using 3% Discount Rate	–$215 + B
–Using 7% Discount Rate	–$210 + B

[a] All costs and benefits are rounded to the nearest $5 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier sections of the chapter.

[b] Note that costs are the total costs of reducing all pollutants, including HAPs and CO, as well as NOx and PM_{10}. Benefits in this table are associated only with PM and NOx reductions.

[c] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 8-13. B is the sum of all unquantified benefits and disbenefits.

[d] Monetized benefits are presented using two different discount rates. Results calculated using 3 percent discount rate are recommended by EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b). Results calculated using 7 percent discount rate are recommended by OMB Circular A-94 (OMB, 1992).

1.0 INTRODUCTION

The regulation under analysis in this report, which is being proposed under Section 112 of the Clean Air Act Amendments of 1990 (CAA), is the National Emission Standard for Hazardous Air Pollutants (NESHAP)for Reciprocating Internal Combustion Engines (RICE). This emission standard would regulate the emissions of certain hazardous air pollutants (HAPs) from certain internal combustion engines. The RICE industry group includes any facility engaged in the use of internal combustion engines to produce power for the production or transmission of final goods in their operating process. This report analyzes the impact that regulatory action is likely to have on the industries affected by the rule, and on society as a whole. Included in this chapter is a summary of the purpose of this regulatory impact analysis (RIA), the statutory history which preceded this regulation, and a description of the content of this report. This report should be read in conjunction with other background documents and supporting analyses, such the determination of the MACT floor memorandum, the memorandum of baseline emissions of HAPs, and the detailed analyses of engineering costs and national impacts. All of these documents are located in the public docket.

1.1 PURPOSE

The President issued Executive Order 12866 on October 4, 1993. It requires EPA to prepare RIAs for all “economically significant” regulatory actions. The criteria set forth in Section 1 of the Order for determining whether a regulation is economically significant are that the rule: (1) is likely to have an annual effect on the economy of $100 million or more, or adversely and materially affect a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or state, local, or tribal governments or communities; (2) is likely to create a serious inconsistency or otherwise interfere with an action taken or planned by another agency; (3) is likely to materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligation of recipients thereof; or (4) is likely to raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in the Executive Order. The EPA has determined that the RICE NESHAP is a "significant" rule because it will have an annual effect on the economy of more than $100 million, and is therefore subject to the requirements of Executive Order 12866. Along with requiring an assessment of benefits and costs, E.O. 12866 specifies that EPA, to the extent allowed by the CAA and court orders, demonstrate (1) that the benefits of the NESHAP regulation will outweigh the costs and (2) that the maximum level of net benefits (including potential economic, environmental, public health and safety and other advantages; distributive impacts; and equity) will be reached. EPA has chosen a single regulatory option for evaluation in this RIA. Benefits and costs are quantified to the greatest extent allowed by available data. As stipulated in E.O. 12866, in deciding whether and how to regulate, EPA is required to assess all costs and benefits of available regulatory alternatives, including the alternative of not regulating. Accordingly, the cost benefit analysis in this report is measured against the baseline, which represents industry and societal conditions in the absence of regulation.

1.2 LEGAL HISTORY AND STATUTORY AUTHORITY

The RICE NESHAP will require sources to achieve emission limits reflecting the application of the maximum achievable control technology (MACT), consistent with sections 112(d) of the CAA. This section provides a brief history of Section 112 of the Act and background regarding the definition of source categories and emission points for Section 112 standards.

Section 112 of the Act provides a list of 189 HAPs and directs the EPA to develop rules to control HAP emissions. The CAA requires that the rules be established for categories of sources of the emissions, rather than being set by pollutant. In addition, the CAA establishes specific criteria for establishing a minimum level of control and criteria to be considered in evaluating control options more stringent than the minimum control level. Assessment and control of any remaining unacceptable health or environmental risk is to occur 8 years after the rules are promulgated.

For the subject NESHAP, EPA chose regulatory options based on control options on an emission point basis. The RICE NESHAP regulates emissions of all HAPs emitted from all emission points at both new and existing RICE sources. An emission point is defined as a point within a facility that operates one or more internal combustion engine(s) which emits one or more HAPs. For RICE units, there is only one emission point for each engine—end-of-pipe emissions after combustion of a fuel source (typically natural gas).

1.3 REPORT ORGANIZATION

Chapter 2 presents information on the need for a regulation of RICE units. This meets the Executive Order 12866 requirement for EPA to promulgate only regulations that are required by law, are necessary to interpret the law, or are necessary due to a compelling public need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well-being of the public. We present the market conditions which necessitate regulatory action, and provide a characterization of the air emissions associated with RICE units, and the significance of the environmental problem which EPA intends to address through the regulation.

Chapter 3 provides a profile of RICE units and the control techniques which were considered for the standard. We then present the a summary of regulatory compliance costs (including the engineering costs associated with the control techniques and monitoring, reporting, and record keeping costs) along with the issues and assumptions upon which the estimates were based.

Chapter 4 provides economic profiles of the industries that operate RICE units, which provides a characterization of the affected industries and presents background data necessary to estimate total social costs of the regulation. Chapter 5 describes the methodology used to estimate the economic effects of the regulation including, predicted price, output, and employment impacts which reflect upon the quantification of the social costs of the regulatory option. We also present a discussion of how this rule may influence purchase decisions for new engines. Chapter 6 then uses the estimated costs and economic impacts to present a screening analysis of firm-level impacts on small and large firms owning RICE units.

Chapter 7 provides a qualitative description of the benefits from several of the pollutants reduced as a result of regulatory action (including, the HAPs of concern - formaldehyde, acetaldehyde, acrolein, and methanol—carbon monoxide, and nitrous oxides). As explained in this chapter, due to data limitations some benefits cannot be quantified in terms of dollar value and therefore we cannot provide a full presentation of monetized benefits for the purpose of comparing with costs.

Chapter 8 provides a quantitative assessment of a portion of the benefits which are identified in Chapter 7; namely, only those benefits associated with health effects of NOx exposures. The methodology used to arrive at these estimates is outlined and any uncertainties and limitations are identified. The quantitative benefits of NOx health effects are then compared with total social costs, recognizing that a large portion of the benefits are not represented in the benefit-cost comparison (including all benefits associated with HAP reductions, CO reductions, and the welfare effects of NOx).

2.0 NEED FOR REGULATION

One of the concerns about potential threats to human health and the environment from internal combustion engines is the emission of HAPs. Health risks from emissions of HAPs into the air include increases in potential cancer incidences in the nasal cavity, trachea, and the respiratory system in general and other toxic effects. This chapter discusses the need for and consequences of regulating of HAP emissions from RICE.

Section 2.1 presents the conditions of market failure which necessitate government intervention. Section 2.2 identifies the insufficiency of political and judicial forces to control the release of toxic air pollutants from internal combustion engines. Section 2.3 provides a characterization of the HAP and other pollutant emissions from RICE, and a summary of the health and welfare risks of these pollutants. Lastly, Section 2.4 identifies the consequences of regulating versus the option of not regulating.

2.1 ENVIRONMENTAL FACTORS WHICH NECESSITATE REGULATION

Regulation of RICE units addresses of the adverse health effects caused by human exposure to HAP emissions. This section characterizes the emissions attributable to RICE and summarizes the adverse health effects associated with human exposure to HAP emissions.

2.1.1 *Air Emission Characterization*

The HAP emissions from RICE units are all organic HAPs as are in section 112(b) of the CAA. HAP emissions from RICE are primarily composed of formaldehyde, acetaldehyde, acrolein, and methanol. The different HAPs emitted have different toxicities, and there are some variations in the concentrations of individual HAPs and the emission release characteristics of different emission points.

Baseline emissions from RICE were estimated using information gathered during a Federal Advisory Committee Act (FACA) process for several source categories of combustion units (Alpha Gamma, 2002a) and provided by vendors of RICE units in response to information collection requests and questionnaires sent out under section 114 of the CAA. For the purpose of calculating baseline emissions and emission reductions, HAP emission factors were calculated for each potentially affected new and existing engine type (spark-ignition two-stroke lean burn (SI2SLB), spark-ignition four-stroke lean burn (SI4SLB), spark-ignition four-stroke rich burn (SI4SRB), and compression-ignition (CI) engines[1]). These factors were estimated from test data contained in the Inventory Database for engines rated at greater than 500 hp, operating at all loads. The total HAP emission factor was calculated by summing the average emission factors for formaldehyde, acetaldehyde, acrolein, and methanol in terms of lb of HAP per hour of engine operation. Table 2-1 contains the HAP emissions factors for each engine configuration in pounds per hour. Emissions are greatest for 2SLB engines, which, on average, emit 0.962 lbs. per hour of HAPs, and least for CI engines, which emit 0.0359 lbs. per hour.

[1]Unless otherwise noted, 2SLB, 4SLB, and 4SRB are used in the remainder of this section to denote spark-ignition engine categories. Compression-ignition engines are referred to as CI throughout the section regardless of the number of engine strokes per cycle. Characteristics of these four RICE design categories are discussed in more detail in Section 3.1.

Table 2-1. HAP Emissions Factors by Engine Configuration (lbs/hour)[a]

Engine Configuration	Emissions Factor (lbs/hour)
2SLB	0.962
4SLB	0.887
4SRB	0.0707
CI	0.0359

[a] The HAP emissions factors presented are the sum of the factors for formaldehyde, acetaldehyde, acrolein, and methanol.

This value was then converted to an annual HAP emission factor in terms of tons of HAP per year for each of the four engine types (2SLB, 4SLB, 4SRB, and CI) using the following equation:

$$(2.1) \qquad HAP\ Emission\ Factor\ \left(\frac{tons}{yr}\right) = \frac{EF_{HAP}\ \left(\frac{lb}{hr}\right)\ *\ 6{,}500\ \left(\frac{hrs}{yr}\right)}{2{,}000\ \left(\frac{lb}{ton}\right)}$$

where EF_{HAP} is the total HAP emissions factor in pounds per hour, 6,500 is the estimated average number of hours of operation per year for engines in the Inventory Database, and 2,000 is the conversion factor between pounds and tons.

Total baseline emissions were estimated for 2005, which was the year chosen for quantitative analysis of the costs and benefits of the RICE NESHAP. Baseline emissions were calculated by multiplying the HAP emission factor generated by applying equation (2.1) for each engine type by the number of engines of that type projected to be subject to the rule in 2005, adjusting for the proportion of each engine type expected to be controlled in the absence of the rule and their level of control. For those engines that are currently controlling formaldehyde emissions or would control them in the future even in the absence of the RICE NESHAP, it was assumed that the same percent reduction achieved for formaldehyde is being achieved for all HAPs. For instance, approximately 27 percent of 4SRB are currently using NSCR to achieve 75 percent reductions in formaldehyde emissions. Therefore, it was assumed that these engines are also achieving 75 percent reductions in all HAPs. To calculate baseline emissions for each engine type, the following relationship was used:

(2.2)
$$\left(\frac{\substack{\text{BaselineHAP}\\ \text{Emissions}\\ \text{tons}}}{\text{yr}}\right) = \left[EF_{HAP}\left(\frac{\text{tons}}{\text{yr}}\right) * Y * N\right] + \left[EF_{HAP}\left(\frac{\text{tons}}{\text{yr}}\right) * (1 - Y) * \frac{(100 - \eta)}{100} * N\right]$$

where EF_{HAP} is the value calculated for that engine type using equation (2.1), Y is the proportion of engines estimated to be uncontrolled in the baseline, N is the number of engines subject to the RICE NESHAP, and 0 is the percent reduction in formaldehyde emissions achieved for those engines that are controlled in the baseline.

Based on a memorandum discussing the distribution of major and area sources of RICE units (Alpha Gamma, 2001a), we anticipate that about 60 percent of existing and future stationary RICE units will be located at area sources. This is because most RICE engines or groups of RICE engines are not major sources of HAP emissions by themselves, but may be major because they are co-located at major HAP sites. Because area sources are not covered by the NESHAP, engines located at area sources will not incur any compliance costs associated with the RICE NESHAP. Thus, only 40 percent of the existing 4SRB engines that are above 500 hp and are not backup/emergency units (the only existing engines that receive costs under the rule) and 40 percent of all RICE projected to be added in the future (above 500 hp that are not backup/emergency units) are expected to be subject to the proposed rule.

For example, for existing 4SRB engines, EF_{HAP} = 0.0707 * 6,500/2,000 = 0.2298, Y is 0.73, N is equal to 4,573 * 0.4 (to adjust for the proportion of engines located at major sources), and 0 is 75 (the values of Y, N, and 0 for other affected engine types are provided later in this section of the report in Tables 2-5 and 2-6). Thus, the estimated level of baseline HAP emissions from existing 4SRB RICE that are subject to the rule is equal to 0.2298 * 0.73 * 4,573 * 0.4 + 0.2298 * 0.27 * 0.25 * 4,573 * 0.4, or 335 tons per year.

Table 2-2 presents the estimated annual baseline HAP emissions from RICE subject to the NESHAP for each type of new and existing engine. Although all existing RICE located at major sources are subject to the rule, the only existing engines that will be required to meet emissions limits under the NESHAP are 4SRB. For the other three potentially affected subcategories, the MACT floor is considered to be no control. Because an above-the-floor option was considered to have excessive costs, existing 2SLB, 4SLB, and CI engines will be subject only to the MACT floor and are not required to add emission control or monitoring equipment. Baseline HAP emissions from existing sources are 27,489 tons per year. As mentioned above, 4SRB are the only subcategory directly affected by the rule, representing about 50 percent of baseline emissions from existing RICE, however, approximately only 3 percent are expected to be located at major sources and apply controls. Baseline HAP emissions from new sources are expected to have reached 19,200 tons per year by 2005. Unlike existing sources, all new sources subject to the rule are required to control HAP emissions. As described above, baseline emissions take into account the current estimated level of emissions control, based on questionnaire responses submitted by vendors and users of RICE units. As a result, baseline HAP and other pollutant emissions reflect the level of control that would be achieved in the absence of the rule.

2.1.2 *Harmful Effects of HAPs*

Exposure to HAPs has been associated with a variety of adverse health effects. Direct exposure to HAPs can occur through inhalation, soil ingestion, the food chain, and dermal contact. Health effects associated with HAP emissions are addressed in this NESHAP. In general, many HAPs are classified as possible, probable, or known human carcinogens, which can result in pain and suffering of individuals associated with leukemia or other cancers and possible death. Other HAPs have not been classified as human carcinogens, but have non-carcinogenic toxic effects. Exposure to these pollutants will also result in adverse health and welfare impacts to human populations.

Table 2-2. National Baseline HAP Emissions from RICE Units, 2005

Type of Engine	Baseline HAP Emissions from All RICE Sources[a] (tons/yr)	Baseline HAP Emissions from Major Sources (tons/yr)
Existing Engines:		
2SLB Clean Gaseous Fuel	13,888	5,555
4SLB Clean Gaseous Fuel	11,729	4,692
4SRB Clean Gaseous Fuel	838	335
Compression Ignition	1,034	414
Subtotal	27,489	10,996
New Engines:		
2SLB Clean Gaseous Fuel	1,565	626
4SLB Clean Gaseous Fuel	15,685	6,274
4SRB Clean Gaseous Fuel	785	314
Compression Ignition	1,165	466
Subtotal	19,200	7,680
Total	46,689[a]	18,676

[a] This includes emissions from both major and area sources.

Table 2-3 lists the possible effects from exposure to HAP emissions. EPA has devised a system, which was adapted from one developed by the International Agency for Research on Cancer (IARC), for classifying chemicals based on the weight-of-evidence (EPA, 1987). Of the HAPs reduced from this proposed regulation, formaldehyde and acetaldehyde are classified as group B, or probable human carcinogens. This means that there is evidence to support that the chemical may cause an increased risk of cancer in humans. Formaldehyde and acetaldehyde are a concern to the EPA because long term exposure to these chemicals have been known to cause lung and nasal cancer in animals and probably humans.

Table 2-3. Potential Health and Welfare Effects Associated with Exposure to Hazardous Air Pollutants

Effect Type	Effect Category	Effect End-Point
Health	Mortality	Carcinogenicity Genotoxicity Non-Cancer lethality
	Chronic Morbidity	Neurotoxicity Immunotoxicity Pulmonary function decrement Liver damage Gastrointestinal toxicity Kidney damage Cardiovascular impairment Hematopoietic (Blood disorders) Reproductive/Developmental toxicity
	Acute Morbidity	Pulmonary function decrement Dermal irritation Eye irritation
Welfare	Materials Damage	Corrosion/Deterioration
	Aesthetic	Unpleasant odors Transportation safety concerns
	Agriculture	Yield reductions/Foliar injury
	Ecosystem Structure	Biomass decrease Species richness decline Species diversity decline Community size decrease Organism lifespan decrease Trophic web shortening

The remaining HAPs reduced by the rule are noncarcinogens. Though they do not cause cancer, they are considered hazardous because of the other significant adverse health effects with which they are associated, such as problems with the central nervous system, irritation of the skin, eyes, or respiratory tract, and many other effects. These adverse effects are discussed in more detail in Chapter 7 of this RIA.

The rule will also produce benefits associated with reductions in CO and NOx. Emissions of CO and NOx have been associated with a variety of health impacts. Human health effects associated with exposure to CO include cardiovascular system and central nervous system (CNS) effects, which are directly related to reduced oxygen content of blood and which can result in modification of visual perception, hearing, motor and sensorimotor performance, vigilance, and cognitive ability.

Emissions of NOx can irritate the lungs and lower resistance to respiratory infection (such as influenza). NOx, together with VOCs, are precursors to the formation of tropospheric ozone. It is exposure to ozone that is responsible for adverse respiratory impacts, including coughing and difficulty in breathing. Repeated exposure to elevated concentrations of ozone over long periods of time may also lead to chronic, structural damage to the lungs. Particulate matter (PM) can also be formed from NOx emissions. Scientific studies have linked PM (alone or in combination with other air pollutants) with a series of health effects. These health effects include premature death and increased hospital admissions and emergency room visits, increased respiratory symptoms and disease, decreased lung function, and alterations in lung tissue and structure and in respiratory tract defense mechanisms. Children, the elderly, and people with cardiopulmonary disease, such as asthma, are most at risk from the health effects of ozone and PM. NOx emissions are also an important precursor to acid rain and may affect both terrestrial and aquatic ecosystems. Atmospheric deposition of nitrogen leads to excess nutrient enrichment problems (“eutrophication”) in the Chesapeake Bay and several nationally important estuaries along the East and Gulf Coasts. Nitrogen dioxide and airborne nitrate also contribute to pollutant haze, which impairs visibility and can reduce residential property values and the value placed on scenic views.

2.2 MARKET FAILURE

The U.S. Office of Management and Budget (OMB) directs regulatory agencies to demonstrate the need for a major rule (OMB, 1992). The RIA must show that a market failure exists and that it cannot be resolved by measures other than Federal regulation. Market failures are categorized by OMB as *externalities*, *natural monopolies*, or *inadequate information*. The operators of RICE units participate in highly competitive industries, thus the natural monopoly condition does not exist; nor does the condition of inadequate information due to the highly organized nature of the affected industries. They do, however, create a negative externality from the effects of the air pollution generated from RICE units. This means that, in the absence of government regulation, the decisions of generators of air pollution do not fully reflect the costs associated with that pollution. For a user of an internal combustion engine, air pollution from the engine is a product or by-product that can be disposed of cheaply by venting it to the atmosphere. Left to their own devices, many users of these engines treat air as a free good and do not fully "internalize" the damage caused by toxic emissions. This damage is born by society, and the receptors (the people who are adversely affected by the pollution) are not able to collect compensation to offset their costs. They cannot collect compensation because the adverse effects, like increased risks of morbidity and mortality, are non-market goods, that is, goods that are not explicitly and routinely traded in organized free markets.

HAP emissions represent an externality in that operations that use RICE impose costs on others outside of the marketplace. In the case of this type of negative externality, the market price of goods and services does not reflect the costs, borne by receptors of the HAPs, generated by the use of these engines. Government regulation, therefore, can be used to improve the situation. For example, the NESHAP will require certain types of internal combustion engines to reduce the quantity of HAPs that are emitted. With the NESHAP in effect, the cost that affected industries must incur to produce products or services that require RICE as an input will more closely approximate the full social costs of production. The more the costs of pollution are internalized by the users of RICE, the greater the improvement in the way the market functions. In the long run, affected industries will be forced to increase the prices of their products and services in order to cover total production costs (including the internalized pollution costs that result from the RICE NESHAP). As market prices rise to better reflect the costs to society imposed by the use of RICE, consumers will reduce their demand for the affected products and services accordingly. As a result of the behavioral changes by consumers and producers, fewer products and services will be provided to the market. The reduction in output will tend to reduce emissions from RICE, which provides benefits to society, but it will also impose costs on producers and consumers.

2.3 INSUFFICIENT POLITICAL AND JUDICIAL FORCES

There are a variety of reasons why many emission sources, in EPA's judgment, should be subject to reasonably uniform national standards. The principal reasons are:

- Air pollution crosses jurisdictional lines.
- The people who breathe the air pollution travel freely, sometimes coming in contact with air pollution outside their home jurisdiction.
- Harmful effects of air pollution detract from the nation's health and welfare regardless of whether the air pollution and harmful effects are localized.
- Uniform national standards, unlike potentially piecemeal local standards, are not likely to create artificial incentives or artificial disincentives for economic development in any particular locality.
- One uniform set of requirements and procedures can reduce paperwork and frustration for firms that must comply with emission regulations across the country.

Because RICE units are typically a small component to a larger operation or production process, and because they are located in a wide variety of manufacturing and service industries, it would be too costly for individuals or small groups to organize and obtain the political or judicial force to reduce the level of air pollution from these sources.

2.4 CONSEQUENCES OF REGULATORY ACTION

To address the health and welfare concern from the emission of HAPs, the proposed rule reduces emissions at "major" sources of RICE HAP emissions (i.e., those that emit more than 10 tons of any one HAP or more than 25 tons of a combination of HAPs). Although the rule does not apply to all RICE units that emit HAPs, it will reduce the magnitude of the negative externality that exists in the affected industries. Below we provide an assessment of the consequences of the attainment of EPA emission reduction objectives, and the likely consequences if these objectives are not met.

2.4.1 *Consequences if EPA's Emission Reduction Objectives are Met*

The EPA collected information and identified four subcategories (or types) of RICE units in operation today that are potentially affected by the RICE NESHAP, including:

- Spark-Ignition, Clean Gaseous Fuel 2-Stroke Lean Burn Engines (2SLB),
- Spark-Ignition, Clean Gaseous Fuel 4-Stroke Lean Burn Engines (4SLB),
- Spark-Ignition, Clean Gaseous Fuel 4-Stroke Rich Burn Engines (4SRB), and
- Compression Ignition Engines (CI).

Table 2-4 and 2-5 present the population of existing and new sources of RICE units (Alpha Gamma, 2002a), broken into the total number of engines in each model category and the number that will be directly affected (i.e., incur compliance costs). These population estimates are based on data contained in the Inventory Database and information provided by the EPA Office of Mobile Sources (now the Office of Transportation and Air Quality) regarding estimated five year sales volume for engines, which was derived from the Power Systems Research database, and confidential sales projection information provided to EPA by engine manufacturers.

Table 2-4. Population of Existing RICE[a]

Engine Subcategory	HP Range[b]	Total Number of Engines	Number of Affected Engines[c]
2SLB Clean Gaseous Fuel	500–1,000	1,412	0
	1,000–5,000	2,726	0
	5,000–10,000	305	0
	Total	4,444	0
4SLB Clean Gaseous Fuel[d]	500–1,000	866	0
	1,000–5,000	3,095	0
	5,000–10,000	188	0
	Total	4,149	0
4SRB Clean Gaseous Fuel[e]	500–1,000	3,353	1,341
	1,000–5,000	1,215	486
	5,000–10,000	5	2
	Total	4,573	1,829
Compression Ignition	500–1,000	5,312	0
	1,000–5,000	3,541	0
	5,000–10,000	None	0
	Total	8,853	0

Source: Alpha Gamma Technologies, Inc.; Memorandum to Sims Roy, U.S. EPA; National Impacts Associated with Reciprocating Internal Combustion Engines; June, 2002a.

[a] The presented population excludes RICE that are used as emergency power units or that are less than 500 HP.

[b] There are no existing RICE greater than 10,000 HP.

[c] The only existing RICE affected by the proposed rule are 4SRB engines located at major sources. The number of affected engines was rounded to the nearest integer in this table for presentation purposes, but fractional engines were used in calculations.

[d] 3 percent of existing 4SLB clean gaseous fuel RICE are controlled with a CO oxidation catalyst.

[e] 27 percent of existing 4SRB clean gaseous fuel RICE are controlled with NSCR.

Table 2-5. Forecasted Population of New RICE, 2005[a]

Engine Subcategory	HP Range[b]	Total New RICE Projected to be Added by 2005	Affected New RICE, 2005[c]
2SLB Clean Gaseous Fuel	500–1,000	500	200
	1,000–5,000	None	0
	5,000–10,000	None	0
	Total	500	200
4SLB Clean Gaseous Fuel[d]	500–1,000	2,124	850
	1,000–5,000	3,412	1,365
	5,000–10,000	12	5
	Total	5,548	2,219
4SRB Clean Gaseous Fuel[e]	500–1,000	1,858	743
	1,000–5,000	2,417	967
	5,000–10,000	8	3
	Total	4,283	1,713
Compression Ignition	500–1,000	5,987	2,395
	1,000–5,000	3,991	1,596
	5,000–10,000	0	0
	Total	9,978	3,991

Source: Alpha Gamma Technologies, Inc.; Memorandum to Sims Roy, U.S. EPA; National Impacts Associated with Reciprocating Internal Combustion Engines; June, 2002a.

[a] The forecasted population of new RICE are assumed for stationary applications not including emergency power units.
[b] It is predicted that no RICE greater than 10,000 HP will be sold during the next five years.
[c] The only existing RICE affected by the proposed rule are 4SRB engines located at major sources. The number of affected engines was rounded to the nearest integer in this table for presentation purposes, but fractional engines were used in calculations.
[d] It is predicted that 3 percent of new 4SLB clean gaseous fuel RICE will be controlled with a CO oxidation catalyst in the absence of this regulation.
[e] It is predicted that 27 percent of new 4SRB clean gaseous fuel RICE will be controlled with NSCR in the absence of this regulation.

2.4.1.1 *Regulatory Alternatives Considered.*

Based on information in our database, we determined the MACT floor for new and existing sources. For existing sources, the MACT floor (defined in the CAA as the average control level achieved by the top 12 percent of similar sources) identifies controls on 4SRB subcategory only, whereas all uncontrolled new sources in each of the five subcategories will be required to control to the new source MACT floor levels (defined in the CAA as the best available control achieved in the subcategory).

Table 2-6 presents the regulatory alternatives considered for this proposal. The first regulatory alternative represents the MACT floor level of performance for engine subcategories. The second regulatory alternative, a more stringent, above-the-floor alternative, was also evaluated. The above-the-floor alternative was developed to introduce an alternative which results in higher HAP emission reductions compared to the MACT floor performance levels. However, EPA determined that the incremental costs associated with the above-the-floor MACT options (with cost per ton over $300,000 for some subcategories) were excessive and are not evaluated in this analysis.

2.4.1.2 *Alternative Regulatory Options Based on Risk*

We have made every effort in developing this proposal to minimize the cost to the regulated community and allow maximum flexibility in compliance options consistent with our statutory obligations. We recognize, however, that the proposal may still require some facilities to take costly steps to further control emissions even though those emissions may not result in exposures which could pose an excess individual lifetime cancer risk greater than one in one million or which exceed thresholds determined to provide an ample margin of safety for protecting public health and the environment from the effects of hazardous air pollutants. We are, therefore, specifically soliciting comment on whether there are further ways to structure the proposed rule to focus on the facilities which pose significant risks and avoid the imposition of high costs on facilities that pose little risk to public health and the environment.

Table 2-6. Summary of Regulatory Alternatives for RICE Subcategories

Engine Subcategory	Regulatory Alternative	Requirement	Performance Level[a]
Existing Sources: 2SLB Clean Gaseous Fuel	MACT Floor	No control	
	Above-the-Floor	Oxidation catalyst	Equipment standard
4SLB Clean Gaseous Fuel	MACT Floor	No control	
	Above-the-Floor	Oxidation catalyst	Equipment standard
4SRB Clean Gaseous Fuel	MACT Floor	NSCR with a required formaldehyde control efficiency and a formaldehyde outlet concentration limit	75 percent CH_2O efficiency or emission limitation of 350 ppbvd CH_2O
Compression Ignition	MACT Floor	No control	
	Above-the-Floor	Oxidation catalyst	Equipment standard
Digester/Landfill	MACT Floor	No control	
	Above-the-Floor	Catalytic control with pretreatment system[b]	Equipment standard
New Sources: 2SLB Clean Gaseous Fuel	MACT Floor	Oxidation catalyst with a required CO control efficiency and a formaldehyde outlet concentration limit	60 percent CO efficiency or emission limitation 17 ppmvd CH_2O
4SLB Clean Gaseous Fuel	MACT Floor	Oxidation catalyst with a required CO control efficiency and a formaldehyde outlet concentration limit	93 percent CO efficiency or emission limitation of 14 ppmvd CH_2O

Table 2-6. Summary of Regulatory Alternatives for RICE Subcategories (continued)

Engine Subcategory	Regulatory Alternative	Requirement	Performance Level[a]
4SRB Clean Gaseous Fuel	MACT Floor	NSCR with a required formaldehyde control efficiency and a formaldehyde outlet concentration limit	75 percent CH_2O efficiency or emission limitation of 350 ppbvd CH_2O
Compression Ignition	MACT Floor	Oxidation catalyst with a required CO control efficiency and a formaldehyde outlet concentration limit	70 percent CO efficiency or emission limitation of 580 ppbvd CH_2O
Digester/Landfill	MACT Floor	No control	

Source: Alpha Gamma Technologies, Inc.; Memorandum to Sims Roy, U.S. EPA; National Impacts Associated with Reciprocating Internal Combustion Engines; June, 2002a.

[a] All concentrations must be corrected to 15 percent oxygen, dry basis.

Representatives of the plywood and composite wood products industry provided EPA with descriptions of three mechanisms that they believed could be used to implement more cost-effective reductions in risk. The docket for today's proposed rule contains "white papers" prepared by industry that outline their proposed approaches (see docket number A-95-35, Item #II-D-9). These approaches could be effective in focusing regulatory controls on facilities that pose significant risks and avoiding the imposition of high costs on facilities that pose little risk to public health or the environment, and we are seeking public comment on the utility of each of these approaches with respect to this rule.

<u>Applicability Cutoffs for Threshold Pollutants Under Section 112(d)(4) of the CAA.</u> The first approach is an "applicability cutoff" for threshold pollutants that is based on EPA's authority under CAA section 112(d)(4) to establish standards for HAP which are "threshold pollutants." A "threshold pollutant" is one for which there is a concentration or dose below which adverse effects are not expected to occur over a lifetime of exposure. For such pollutants, section 112(d)(4) allows EPA to consider the threshold level, with an ample margin of safety, when establishing emission standards. Specifically, section 112(d)(4) allows EPA to establish emission standards that are not based upon the maximum achievable control technology (MACT) specified under section 112(d)(2) for pollutants for which a health threshold has been established. Such standards may be less stringent than MACT. Historically, EPA has interpreted section 112(d)(4) to allow categories of sources that emit only threshold pollutants to avoid further regulation if those emissions result in ambient levels that do not exceed the threshold, with an ample margin of safety.[2]

A different interpretation would allow us to exempt individual facilities within a source category that meet the section 112(d)(4) requirements. There are three potential scenarios under this interpretation of the section 112(d)(4) provision. One scenario would allow an exemption for individual facilities that emit only threshold pollutants and can demonstrate that their emissions of threshold pollutants would not result in air concentrations above the threshold levels, with an ample margin of safety, even if the category is otherwise subject to MACT. A second scenario would allow the section 112(d)(4) provision to be applied to both threshold and

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[2]See 63 FR 18503, 18765 (April 15, 1998) (Pulp and Paper I NESHAP).

non-threshold pollutants, using the 1 in a million cancer risk level for decisionmaking for non-threshold pollutants. A third scenario would allow a section 112(d)(4) exemption at a facility that emits both threshold and non-threshold pollutants. For those emission points where only threshold pollutants are emitted and where emissions of the threshold pollutants would not result in air concentrations above the threshold levels, with an ample margin of safety, those emission points could be exempt from the MACT standard. The MACT standard would still apply to the non-threshold emissions from the source. For this third scenario, emission points that emit a combination of threshold and non-threshold pollutants that are co-controlled by MACT would still be subject to the MACT level of control. However, any threshold HAP eligible for exemption under section 112(d)(4) that are controlled by control devices different from those controlling non-threshold HAP would be able to use the exemption, and the facility would still be subject to the parts of the standard that control non-threshold pollutants or that control both threshold and non-threshold pollutants.

<u>Estimation of hazard quotients and hazard indices.</u> Under the section 112(d)(4) approach, EPA would have to determine that emissions of each of the threshold pollutants emitted by RICE sources at the facility do not exceed the threshold levels, with an ample margin of safety. The common approach for evaluating the potential hazard of a threshold air pollutant is to calculate a "hazard quotient" by dividing the pollutant's inhalation exposure concentration (often assumed to be equivalent to its estimated concentration in air at a location where people could be exposed) by the pollutant's inhalation Reference Concentration (RfC). An RfC is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure that, over a lifetime, likely would not result in the occurrence of adverse health effects in humans, including sensitive individuals. The EPA typically establishes an RfC by applying uncertainty factors to the critical toxic effect derived from the lowest- or no-observed-adverse-effect level of a pollutant (EPA, 1994). A hazard quotient less than one means that the exposure concentration of the pollutant is less than the RfC, and, therefore, presumed to be without appreciable risk of adverse health effects. A hazard quotient greater than one means that the exposure concentration of the pollutant is greater than the RfC. Further, EPA guidance for assessing exposures to mixtures of threshold pollutants recommends calculating a "hazard index" by summing the individual hazard quotients for those pollutants in the mixture that affect

the same target organ or system by the same mechanism (EPA, 2000d). Hazard index (HI) values would be interpreted similarly to hazard quotients; values below one would generally be considered to be without appreciable risk of adverse health effects, and values above one would generally be cause for concern.

For the determinations discussed herein, EPA would generally plan to use RfC values contained in EPA’s toxicology database, the Integrated Risk Information System (IRIS). When a pollutant does not have an approved RfC in IRIS, or when a pollutant is a carcinogen, EPA would have to determine whether a threshold exists based upon the availability of specific data on the pollutant's mode or mechanism of action, potentially using a health threshold value from an alternative source, such as the Agency for Toxic Substances and Disease Registry (ATSDR) or the California Environmental Protection Agency (CalEPA). Table 2-7 provides RfC’s, as well as unit risk estimates, for the HAP emitted by facilities in the RICE source category. A unit risk estimate is defined as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 :g/m3 in air.

To establish an applicability cutoff under section 112(d)(4), EPA would need to define ambient air exposure concentration limits for any threshold pollutants involved.

There are several factors to consider when establishing such concentrations. First, we would need to ensure that the concentrations that would be established would protect public health with an ample margin of safety. As discussed above, the approach EPA commonly uses when evaluating the potential hazard of a threshold air pollutant is to calculate the pollutant’s hazard quotient, which is the exposure concentration divided by the RfC.

Table 2-7. Dose-Response Assessment Values for HAP Reported Emitted by the RICE Source Category.

Chemical Name	CAS No.	Reference Concentration[a] (mg/m^3)	Unit Risk Estimate[b] ($1/(ug/m^3)$)
Acetaldehyde	75-07-0	9.0E-03 (IRIS)	2.2E-06 (IRIS)
Acrolein	107-02-8	2.0E-05 (IRIS)	
Formaldehyde	50-00-0	9.8E-03 (ATSDR)	1.3E-05 (IRIS)
Methanol	67-56-1	4.0E+00 (CAL)	

Sources:
IRIS = EPA Integrated Risk Information System (http://www.epa.gov/iris/subst/index.html).
ATSDR = U.S. Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/mrls.html).
CAL = California Office of Environmental Health Hazard Assessment (http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html).
HEAST = EPA Health Effects Assessment Summary Tables (EPA, 1997b).

[a] Reference Concentration: An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups which include children, asthmatics and the elderly) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from various types of human or animal data, with uncertainty factors generally applied to reflect limitations of the data used.

[b] Unit Risk Estimate: The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 :g/m3 in air. The interpretation of the Unit Risk Estimate would be as follows: if the Unit Risk Estimate = 1.5 x 10-6 per :g/m3, 1.5 excess tumors are expected to develop per 1,000,000 people if exposed daily for a lifetime to 1 :g of the chemical in 1 cubic meter of air. Unit Risk Estimates are considered upper bound estimates, meaning they represent a plausible upper limit to the true value. (Note that this is usually not a true statistical confidence limit.) The true risk is likely to be less, but could be greater.

EPA's "*Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*" (EPA, 2000f) suggests that the noncancer health effects associated with a mixture of pollutants ideally are assessed by considering the pollutants' common mechanisms of toxicity. The guidance also suggests, however, that when exposures to mixtures of pollutants are being evaluated, the risk assessor may calculate a hazard index (HI). The recommended method is to calculate multiple hazard indices for each exposure route of interest, and for a single specific toxic effect or toxicity to a single target organ. The default approach recommended by the guidance is to sum the hazard quotients for those pollutants that induce the same toxic effect or affect the same target organ. A mixture is then assessed by several HIs, each representing one toxic effect or target organ. The guidance notes that the pollutants included in the HI calculation are any pollutants that show the effect being assessed, regardless of the critical effect upon which the RfC is based. The guidance cautions that if the target organ or toxic effect for which the HI is calculated is different from the RfC's critical effect, then the RfC for that chemical will be an overestimate, that is, the resultant HI potentially may be overprotective. Conversely, since the calculation of an HI does not account for the fact that the potency of a mixture of HAP can be more potent than the sum of the individual HAP potencies, an HI may potentially be underprotective.

Options for establishing a hazard index limit. One consideration in establishing a hazard index limit is whether the analysis considers the total ambient air concentrations of all the emitted HAP to which the public is exposed.[3] There are at least several options for establishing a hazard index limit for the section 112(d)(4) analysis that reflect, to varying degrees, public exposure.

One option is to allow the hazard index posed by all threshold HAP emitted from RICE sources at the facility to be no greater than one. This approach is protective if no additional threshold HAP exposures would be anticipated from other sources in the vicinity of the facility or through other routes of exposure (e.g., through ingestion).

A second option is to adopt a "default percentage" approach, whereby the hazard index limit of the HAP emitted by the facility is set at some percentage of one (e.g., 20 percent or 0.2). This approach recognizes the fact that the facility in question is only one of many sources of threshold HAP to which people are typically exposed every day. Because noncancer risk assessment is predicated on total exposure or dose, and because risk assessments to focus only on an individual source, establishing a hazard index limit of 0.2 would account for an assumption that 20 percent of an individual's total exposure is from that individual source. For the purposes of this discussion, we will call all sources of HAP, other than the facility in question, "background" sources. If the facility is allowed to emit HAP such that its own impacts could result in HI values of one, total exposures to threshold HAP in the vicinity of the facility could be substantially greater than one due to background sources, and this would not be protective of public health, since only HI values below one are considered to be without appreciable risk of adverse health effects. Thus, setting the hazard index limit for the facility at

[3]Senate Debate on Conference Report (October 27, 1990), reprinted in "A Legislative History of the Clean Air Act Amendments of 1990," Comm. Print S. Prt. 103-38 (1993) ("Legis. Hist.") at 868.

some default percentage of one will provide a buffer which would help to ensure that <u>total</u> exposures to threshold HAP near the facility (i.e., in combination with exposures due to background sources) will generally not exceed one, and can generally be considered to be without appreciable risk of adverse health effects.

A third option is to use available data (from scientific literature or EPA studies, for example) to determine background concentrations of HAP, possibly on a national or regional basis. These data would be used to estimate the exposures to HAP from non-RICE sources in the vicinity of an individual facility. For example, the EPA's National-scale Air Toxics Assessment (NATA) (EPA, 2002c) and ATSDR's Toxicological Profiles (ATSDR, 2002) contain information about background concentrations of some HAP in the atmosphere and other media. The combined exposures from RICE sources and from other sources (as determined from the literature or studies) would then not be allowed to exceed a hazard index limit of one.

A fourth option is to allow facilities to estimate or measure their own facility-specific background HAP concentrations for use in their analysis.

<u>Tiered analytical approach for predicting exposure.</u> Establishing that a facility meets the cutoffs established under section 112(d)(4) will necessarily involve combining estimates of pollutant emissions with air dispersion modeling to predict exposures. The EPA envisions that we would promote a tiered analytical approach for these determinations. A tiered analysis involves making successive refinements in modeling methodologies and input data to derive successively less conservative, more realistic estimates of pollutant concentrations in air and estimates of risk.

As a first tier of analysis, EPA could develop a series of simple look-up tables based on the results of air dispersion modeling conducted using conservative input assumptions. By specifying a limited number of input parameters, such as stack height, distance to property line, and emission rate, a facility could use these look-up tables to determine easily whether the emissions from their sources might cause a hazard index limit to be exceeded.

A facility that does not pass this initial conservative screening analysis could implement increasingly more site-specific but more resource-intensive tiers of analysis using EPA-approved modeling procedures, in an attempt to demonstrate that exposure to emissions from the facility does not exceed the hazard index limit. The EPA's guidance could provide the basis for conducting such a tiered analysis (EPA, 1992c). It is also possible that ambient monitoring data could be used to supplement or supplant the tiered modeling approach described above. It is envisioned that the appropriate monitoring to support such a determination could be extensive.

Accounting for dose-response relationships. In the past, EPA routinely treated carcinogens as non-threshold pollutants. The EPA recognizes that advances in risk assessment science and policy may affect the way EPA differentiates between threshold and nonthreshold HAP. The EPA's draft Guidelines for Carcinogen Risk Assessment (EPA, 1999b) suggest that carcinogens be assigned non-linear dose-response relationships where data warrant. Moreover, it is possible that dose-response curves for some pollutants may reach zero risk at a dose greater than zero, creating a threshold for carcinogenic effects. It is possible that future evaluations of the carcinogens emitted by this source category would determine that one or more of the carcinogens in the category is a threshold carcinogen or is a carcinogen that exhibits a non-linear dose-response relationship but does not have a threshold.

The dose-response assessments for formaldehyde and acetaldehyde are currently undergoing revision by the EPA. As part of this revision effort, EPA is evaluating formaldehyde and acetaldehyde as potential non-linear carcinogens. The revised dose-response assessments will be subject to review by the EPA Science Advisory Board, followed by full consensus review, before adoption into the EPA Integrated Risk Information System (IRIS). At this time, EPA estimates that the consensus review will be completed by the end of 2003. The revision of the dose-response assessments could affect the potency factors of these HAP, as well as their status as threshold or nonthreshold pollutants. At this time, the outcome is not known. In addition to the current reassessment by EPA, there have been several reassessments of the toxicity and carcinogenicity of formaldehyde in recent years, including work by the World Health Organization and the Canadian Ministry of Health.

If the section 112(d)(4) approach were adopted, the rulemaking would likely indicate that the requirements of the rule do not apply to any source that demonstrates, based on a tiered approach that includes EPA-approved modeling of the affected source's emissions, that the anticipated HAP exposures do not exceed the specified hazard index limit.

2.4.1.2.1 Subcategory Delisting Under Section 112(c)(9)(B) of the CAA

EPA is authorized to establish categories and subcategories of sources, as appropriate, pursuant to CAA section 112(c)(1), in order to facilitate the development of MACT standards consistent with section 112 of the CAA. Further, section 112(c)(9)(B) allows EPA to delete a category (or subcategory) from the list of major sources for which MACT standards are to be developed when the following can be demonstrated: 1) in the case of carcinogenic pollutants, that "no source in the category . . . emits [carcinogenic] air pollutants in quantities which may cause a lifetime risk of cancer greater than one in one million to the individual in the population who is most exposed to emissions of such pollutants from the source"; 2) in the case of pollutants that cause adverse noncancer health effects, that "emissions from no source in the category or subcategory . . . exceed a level which is adequate to protect public health with an ample margin of safety"; and 3) in the case of pollutants that cause adverse environmental effects, that "no adverse environmental effect will result from emissions from any source."

Given these authorities and the suggestions from the white paper prepared by industry representatives (see docket number A-95-35, Item # II-D-9), EPA is considering whether it would be possible to establish a subcategory of facilities within the larger RICE category that would meet the risk-based criteria for delisting. Such criteria would likely include the same requirements as described previously for the second scenario under the section 112(d)(4) approach, whereby a facility would be in the low-risk subcategory if its emissions of threshold pollutants do not exceed the HI limits and if its emissions of non-threshold pollutants do not exceed a cancer risk level of 10^{-6}.

Since each facility in such a subcategory would be a low-risk facility (i.e., if each met these criteria), the subcategory could be delisted in accordance with section 112(c)(9), thereby limiting the costs and impacts of the proposed MACT rule to only those facilities that do not qualify for subcategorization and delisting. EPA estimates that the maximum potential effect of this approach would be the same as that of applying the section 112(d)(4) approach that allows exemption of facilities emitting threshold and non-threshold pollutants if exemption criteria are met.

Facilities seeking to be included in the delisted subcategory would be responsible for providing all data required to determine whether they are eligible for inclusion. Facilities that could not demonstrate that they are eligible to be included in the low-risk subcategory would be subject to MACT and possible future residual risk standards.

Establishing that a facility qualifies for the low-risk subcategory under section 112(c)(9) will necessarily involve combining estimates of pollutant emissions with air dispersion modeling to predict exposures. The EPA envisions that we would employ the same tiered analytical approach described earlier in the section 112(d)(4) discussion for these determinations.

Another approach under section 112(c)(9) would be to define a subcategory of facilities within the RICE source category based upon technological differences, such as differences in production rate, emission vent flow rates, overall facility size, emissions characteristics, processes, or air pollution control device viability. If it could then be determined that each source in this technologically-defined subcategory presents a low risk to the surrounding community, the subcategory could then be delisted in accordance with section 112(c)(9).

If this section 112(c)(9) approach were adopted, the rulemaking would likely indicate that the rule does not apply to any source that demonstrates that it belongs in a subcategory which has been delisted under section 112(c)(9).

2.4.1.3 *Allocation of Resources*.

One of the consequences of the proposed rule is that there will be improved allocation of society's resources associated with RICE. The negative externality of treating air pollution as a free good results in production costs that are less than the optimal level to society (a level that would incorporate the costs associated with the air pollution). Thus, the output levels in the affected industries that utilize RICE units also exceed the optimal level to society. With this rule, the costs of the harmful effects of the processes that use these engines will be internalized by the producers. This, in turn, will affect consumers' purchasing decisions. To the extent these newly-internalized costs are then passed along to the end users of products from industries that utilize RICE units in their production process, and to the extent that these end users are free to buy as much or as little of these products as they wish, they will purchase less (relative to their purchases of other competing services). If this same process of internalizing negative externalities occurs throughout all of the affected industries, an economically optimal situation is approached. This is the situation in which the marginal cost of resources devoted to productions of products that utilize RICE during production processes equals the marginal value of the products to the end users of these products. Although there are uncertainties in this progression of impacts, in the aggregate and in the long run, the NESHAP will move society toward this economically optimal situation.

2.4.1.4 *Emissions Reductions and Cost Impacts*.

The environmental impact of the rule includes the reduction of HAP, CO, NOx, and PM emissions and are presented relative to the baseline, which represents the level of control in the absence of the proposed rule. The estimates include the impacts of applying control to: (1) existing RICE units and (2) additional RICE units that are expected to begin operation by 2005. Thus, the overall estimates represent annual impacts occurring in 2005. Under the proposed rule, it is estimated that the emissions of HAP from RICE units would be reduced by about 5,000 tons per year (approximately 200 tons per year from existing sources and 4,800 tons per year from new sources), emissions of CO would be reduced by 234,400 tons per year, emissions of NOx would be reduced by 167,900 tons per year, and directly emitted PM will be reduced by approximately 3,700 tons per year. Emission levels of other air pollutants (VOC) were not quantified.

The cost impact of the rule includes the capital cost of new control equipment, the associated operation and maintenance cost, and the cost of monitoring, recordkeeping, and reporting. Under the proposed rule, it has been determined that oxidation catalysts, such as CO oxidation catalyst and non-selective catalytic reduction (NSCR), are applicable controls for the reduction of HAP from RICE. Cost impacts include the total capital investment of new oxidation catalyst or NSCR equipment, the cost of energy (utilities) required to operate the control equipment, operation and maintenance costs, and the cost of monitoring, reporting, and record keeping. For 2SLB and 4SLB burn clean gaseous fuel engines, and compression ignition engines, the annualized monitoring costs ranged from $5,959/year to $58,800/year. For 4SRB clean gaseous fuel engines, the annualized monitoring costs ranged from $6,496/year to $21,618/year.

Total control costs and total annual control costs for affected RICE units are presented in Table 2-8. For the MACT floor for existing 4SRB clean gaseous fuel engines, the estimated total capital investment is $68.4 million and the total annualized cost is $38.1 million (1998 dollars). For the MACT floor for new sources, the estimated total capital investment is $372.2 million and the total annualized cost is $215.6 million for new sources projected to enter by 2005. Overall, the total annualized compliance costs in 2005 across both new and existing sources are estimated to be $253.7 million.

Considering total annualized capital costs, monitoring, reporting, and record keeping costs at all affected sources along with behavioral responses in the affected markets (see Section 5 for further discussion of the economic model), this proposed rule has estimated total social costs of approximately $253.7 million in the 5th year after implementation. The estimated social costs differs only very slightly from the estimated engineering compliance costs (excluding behavioral adjustments) in this case (about $20,000 less) because the resulting price changes in each affected market are so small that there is little behavioral response by consumers and producers.

2.4.1.5 *Energy Impacts*.

Energy impacts associated with this regulation would be due to additional energy consumption that the proposed regulation would require by installing and operating control equipment. The only energy requirement for the operation of the control technologies is due to a small increase in fuel consumption resulting from back pressure caused by the control system. This energy impact is however considered minimal in comparison to cost of other impacts, and is therefore considered negligible.

Table 2-8. Summary of HAP Emission Reductions and Cost Impacts Associated with the RICE NESHAP, 2005

Engine Subcategory	Existing				New			
	Baseline Emissions (ton/yr)	HAP Emission Reduction (ton/yr)	Total Capital Investment ($1,000)[a]	Total Annualized Cost ($1,000)[a]	Baseline Emissions (ton/yr)	HAP Emission Reduction (ton/yr)[b]	Total Capital Investment ($1,000)[a]	Total Annualized Cost ($1,000)[a]
2SLB Clean Gaseous Fuel	5,555	0	0	0	626	250	5,846	3,122
4SLB Clean Gaseous Fuel	4,692	0	0	0	6,274	4,034	109,468	65,774
4SRB Clean Gaseous Fuel	335	230	68,370	38,125	314	216	91,098	47,853
Compression Ignition	414	0	0	0	466	302	165,752	98,852
Total:	10,996	230	68,370	38,125	7,680	4,802	372,164	215,601

[a] Total capital investment and total annual costs include the cost of monitoring. Monitoring costs were calculated based on selecting option 1 for 2SLB and 4SLB clean gaseous fuel, and for compression ignition engines greater than or equal to 5000 HP, and selecting option 3 for 2SLB and 4SLB clean gaseous fuel, and compression ignition engines between 500 HP and 5000 HP. Monitoring costs were calculated based on selecting option 5 for 4SRB clean gaseous fuel engines greater than or equal to 5000 HP, and selecting option 6 for 4SRB clean gaseous fuel engines between 500 HP and 5000 HP.

2.4.1.6 *State Regulation and New Source Review*.

Many RICE emit significant quantities of NOx and sometimes CO. States in the Northeast U.S. and to a lesser extent in other parts of the U.S. have required that reasonably available control technology (RACT) be installed on many existing engines for control of NOx. These RACT controls vary from state to state. In some cases RACT NOx controls require the use of ignition enhancement or ignition retard which achieves a NOx reduction of about 10 to 15 percent. In other cases, RACT NOx control may be low emission combustion (LEC) technology which can reduce NOx emissions by 80 to 90 percent. Finally, in other cases, selective catalytic reduction (SCR) and NSCR technologies have been installed to meet RACT requirements. SCR and NSCR can reduce NOx emissions by 90 percent. Existing 4SRB RICE have already added any required NOx or CO controls needed to meet state, local or federal requirements. A new engine going into the Northeast U.S. or any area where RACT is currently required would be expected to control NOx to similar levels as existing engines are currently required.

Existing 2SLB, 4SLB, and CI are not required to install MACT controls. Under the provisions of the NOx SIP call, however, large (> 2500HP and/or 1 ton/day NOx emissions) new 2SLB, 4SLB, and CI engines will have to reduce NOx emissions potentially beyond the RACT level in the NOx SIP call region (21 Eastern U.S. States and the District of Columbia) by 2007. The NOx SIP call is a rulemaking meant to help the Northeastern states meet the 1-hour ozone National Ambient Air Quality Standard (NAAQS). To estimate the potential impact of the RICE MACT rule in the states affected by the NOx SIP call, queries on the RICE Inventory Database were performed to determine the number of engines, size, and controls applied to each type of engine in these states. Information from the Database indicates that selective catalytic reduction (SCR) is being applied to two CI engines. Catalytic reduction, including oxidation catalysts and NSCR, is being applied to a total of 30 engines in the database (14 4SRB and 16 CI). There are additional engines with existing controls, but none of these controls are considered applicable techniques for reducing HAP from RICE (Alpha-Gamma, 2002b).

The installation of groups of new engines or even one large new engine may trigger new source review (NSR) in a non-attainment area for NOx or CO, or prevention of significant deterioration (PSD) in an attainment area for NOx or CO, because of the magnitude of uncontrolled emissions of NOx or CO emissions. In such cases lowest achievable emission reduction (LAER) technology or best available control technology (BACT) would have to be installed. The NSCR technology for 4SRB engines can reduce NOx by 90 percent and selective catalytic reduction (SCR) technology can also reduce NOx by similar amounts. Since NSCR will achieve the MACT standard and also the NOx and CO standards, no additional impacts are expected for this type of engine for existing and new engines as a result of the RICE MACT. For new 2SLB, 4SLB, and CI engines, it would be expected that RACT NOx controls may be required. No additional CO controls would be required since oxidation catalyst systems also reduce CO in addition to HAPs. It is also expected that some of the larger engines that can trigger NSR/PSD review will have to add NOx controls such as SCR in addition to controls required by the RICE MACT oxidation catalyst systems. We expect these cases to be limited in number.

No existing control technologies are in place specifically to address the reduction of HAPs from RICE. There are several existing control techniques designed to reduce other emissions from RICE that could potentially reduce HAP emissions. However, EPA has determined that, among existing add-on controls, controls that involve oxidation are the most likely to reduce HAP emissions from RICE. For rich burn engines, the only currently known applicable technology is NSCR. The only known applicable technology for lean burn engines is the use of oxidation catalysts. There are three other control technologies that could potentially reduce HAP emissions from RICE: air injection, particulate traps, and catalyzed diesel particulate filters. However, the effectiveness of HAP reduction has not been demonstrated for any of these technologies. No other current control device is considered to be applicable for HAP emission reductions from RICE.

For those engines that have installed or will install NSCR or oxidation catalysts to meet restrictions on NOx or other emissions, HAP emissions are reduced incidentally. This has been taken into account in calculating baseline emissions and the incremental emission reductions that will be achieved by the RICE NESHAP. Searches of EPA's RACT/BACT/LAER Clearinghouse (RBLC), California's BACT Clearinghouse, and the RICE Inventory Database were conducted to estimate the number of existing RICE that are equipped with these controls. In addition, several state environmental agencies, EPA regions, and catalyst vendors were contacted to gather more information. The search revealed very few installations of oxidation catalysts. Based on searches of EPA's RBLC database, only five facilities permitted in the last three years have stationary RICE equipped with an oxidation catalyst. The states and EPA regions contacted indicated there were very few or zero facilities in their areas that are known to use oxidation catalysts. A catalyst vendor contacted by EPA indicated that 4,000 catalysts have been installed on stationary RICE since 1985. This vendor projects 200 catalyst installations per year, with approximately 60 percent being oxidation catalysts and the other 40 percent NSCR. Estimates based on information regarding existing engines in the Inventory Database indicate that 27 percent of existing 4SRB are equipped with NSCR, 3 percent of existing 4SLB are using oxidation catalysts, and no existing 2SLB or CI engines were identified as using either (Alpha-Gamma, 2002b). Based on the information gathered, EPA estimates that 27 percent of existing and new 4SRB, 3 percent of existing and new 4SLB, and 0 percent of existing and new 2SLB and CI RICE would be controlled in the absence of this NESHAP.

2.4.1.7 *Other Federal Programs*.

No other Federal programs are known except as discussed in 2.4.1.5.

2.4.2 *Consequences if EPA's Emission Reduction Objectives are Not Met*

The most obvious consequence of failure to meet EPA's emission reduction objectives would be emissions reductions and benefits that are not as large as is projected in this report. However, costs are not likely to be as large either. Whether it is noncompliance from ignorance or error, or from willful intent, or simply slow compliance due to owners and/or operators exercising legal delays, poor compliance can save some producers money. Unless states respond by allocating more resources into enforcement, then poor compliance could bring with it smaller aggregate nationwide control costs. EPA has not included an allowance for poor compliance in its estimates of emissions reductions, due to the fact that poor compliance is unlikely. Also, if the emission control devices degraded rapidly over time or in some other way did not function as expected, there could be a misallocation of resources. This situation is very unlikely, given that the NESHAP is based on demonstrated technology.

3.0 PROFILE OF RICE UNITS AND TECHNOLOGIES

EPA identified 26,832 engines located at commercial, industrial, and government facilities based on information contained in the EPA Inventory Database V.4—Internal Combustion (IC) Engines (referred to as the Inventory Database). The list of engines in this database was itself developed from information in the Aerometric Information Retrieval System (AIRS) and Ozone Transport Assessment Group (OTAG) databases and state and local permit records. As part of the Industrial Combustion Coordinated Rulemaking (ICCR) FACA process, industry and environmental stakeholders reviewed the engines units in the EPA Inventory Database. These stakeholders contributed to the Inventory Database by identifying and including omitted units. From this initial population of 26,832 engines, there were 10,118 engines that were excluded from further analysis because they were either less than 500 hp or used to supply emergency/backup power or both. These engines are not covered by the proposed regulation. Of the 16,714 remaining engines in the Inventory Database that are potentially affected by the rule, 2,645 units had sufficient information to assign model numbers (e.g., fuel type, engine configuration, horsepower). These 2,645 units were linked to 834 existing facilities. These engines are primarily in either the oil and gas extraction industry or the natural gas transmission industry. Because the only existing RICE units affected by the rules are SI4SRB, most of the engines in the database would not have any control costs. Only 889 of the 2,645 existing engines in the database with sufficient information to assign a model number are expected to incur control costs. However, the database is assumed to be representative of the industries where new engines will be added in the future. This section provides background information on RICE technologies, the units and facilities in the Inventory Database, and engines population estimates. Also included is a discussion of pollutants associated with these units and the cost of installing control technologies.

As mentioned in Section 2, EPA anticipates that about 60 percent of existing and future stationary RICE units are currently or will be located at area sources (Alpha Gamma, 2001a). This is because most RICE engines or groups of RICE engines are not major HAP emission sources by themselves, but may be major because they are co-located at major HAP sites. Because area sources are not covered by the NESHAP, engines located at area sources will not incur any compliance costs associated with the RICE NESHAP. Thus, only 40 percent of the existing SI4SRB engines (the only existing engines with costs under the rule) and 40 percent of all RICE projected to be added in the future (that are above 500 hp and are not backup/emergency units) are expected to be directly affected by the proposed rule.

3.1 ENGINES TECHNOLOGIES

The IC engines affected by the regulation are of four design categories as discussed in Section 1: SI2SLB, SI4SLB, and SI4SRB, and CI.[1] In an IC engine, a mixture of air and fuel is burned in engine cylinders. A series of pistons and a crankshaft convert the energy of the expanding gases into mechanical work. Apart from the method of ignition, SI or CI, and the number of strokes, two or four, engines are differentiated by their air-to-fuel (A/F) ratio. As defined by the Gas Research Institute (GRI, 2000), the relative proportions of air and fuel are expressed as the mass of air to that of fuel and is called the A/F ratio. The A/F ratio is called "stoichiometric" if the mixture contains the minimum amount of air that supplies sufficient oxygen to complete combustion of the fuel. Rich burn engines operate near the fuel-air stoichiometric limit with excess oxygen levels less than 4 percent. Lean burn engines operate with significantly higher excess oxygen levels (GRI, 2000). The majority of the information contained in this section is from the Gas Research Institute's publication, "Engine Design, Operation, and Control in the Natural Gas Industry" (GRI, 2000).

[1]Unless otherwise noted, 2SLB, 4SLB, and 4SRB are used in the remainder of this section to denote spark-ignition engine categories. Compression-ignition engines are referred to as CI throughout the section regardless of the number of engine strokes per cycle.

3.1.1 *SI Two-Stroke Engines*

A two-stroke engine completes the power cycle in one revolution of the crankshaft. The crankshaft in an IC engine is attached to the pistons. When the pistons move up and down, the crankshaft turns and converts the reciprocating motion of the pistons into rotary motion. The first stroke begins with the piston at the top of the cylinder. At this time, the engine's combustion chamber contains a compressed mixture of fuel and air. The mixture is ignited by a spark that causes a sudden increase in temperature and pressure that forces the piston downward, transferring power to the crankshaft. As the piston travels downward, air and exhaust ports are uncovered, allowing combustion gases to exit and fresh air to enter. During the second stroke, the air and exhaust ports close and fuel is injected into the cylinder. As the piston returns to its starting position, the upward motion compresses the fuel and air mixture. When the piston reaches the top of the cylinder, the compressed fuel and air mixture is ignited again and the cycle begins again.

Because fresh air is used to clear combustion gases from the cylinder, two-stroke engines operate with an A/F ratio greater than stoichiometric and are, therefore, all of the "lean-burn" design type. A/F ratios for 2SLB engines range between 20:1 and 60:1. Their exhaust temperatures are normally between 550 and 800°F. All 2SLB engines are direct-injected (i.e., fuel is injected directly into the cylinder) (GRI, 2000).

3.1.2 *SI Four-Stroke Engines*

A four-stroke engine completes the power cycle in two revolutions of the crankshaft. The first stroke is the intake stroke during which the intake valve opens and the exhaust valve closes. The downward motion of the piston draws air (direct injected) or a mixture of air and fuel (premixed) into the cylinder. During the second stroke, the intake valve closes, and the fuel is injected (direct injected) into the cylinder as the piston moves upward to compress the air and fuel mixture. As the piston finishes its upward stroke, a spark ignites the mixture, causing a sudden increase in temperature and pressure. The increased pressure drives the piston downward (i.e., the third stroke), delivering power to the crankshaft. During the fourth stroke, the exhaust valve opens and the piston moves upwards to force the exhaust gases out of the cylinder. The regulation will affect two types of spark ignition, four-stroke engines: 4SLB and 4SRB.

Four-Stroke Lean Burn. Compared to the 2SLB engine, the 4SLB engine reduces the presence of high fuel concentration and temperature gradients in the cylinder by mixing the air and fuel during the second stroke. Compared to a 4SRB engine, the increased A/F ratio in 4SLB engines reduces combustion and exhaust temperatures. A/F ratios for this engine configuration are similar to those of 2SLB engines.

Four-Stroke Rich Burn. 4SRB engines have A/F ratios near stoichiometric, meaning that in these engines the proportion of fuel relative to air is greater than in lean-burn engines. All turbo-charged engines that do not introduce fresh air to sweep combustion gases out of the cylinder after ignition are 4SRB engines (GRI, 2000). A/F ratios for these engines typically range between 16:1 and 20:1. Exhaust temperature is higher in rich-burn engines than in lean-burn engines.

3.1.3 *Compression Ignition Units*

CI units almost always operate as lean burn engines. They can be configured as either 2SLB or 4SLB; the distinction is that CI engines are fueled by distillate fuel oil (diesel oil), not by natural gas. Fuel consumption is an important determinant in the type of emissions from these units; combustion of natural gas and combustion of diesel oil may each have separate types and proportions of emissions. Because of this difference in fuel consumption, the type of control equipment, and thus cost, varies from natural gas-fueled units, even if those using diesel are of the same engine configuration and horsepower (hp).

3.2 EMISSIONS

The proposed regulation aims to reduce HAP emissions. HAPs of concern include formaldehyde, acetaldehyde, acrolein, and methanol. Without the regulation, annual HAP emissions from sources subject to the RICE NESHAP are estimated to be 18,700 tons each year by 2005. The proposed regulation will decrease emissions from existing sources by approximately 200 tons per year and emissions from new sources by about 4,800 tons per year by 2005. Estimation of baseline emissions and emission reductions is described further in Section 2.

Emissions factors differ substantially between engine configurations. Table 3-1 contains the HAP emissions factors for each engine configuration in pounds per hour. Emissions are greatest for 2SLB engines, which, on average, emit 0.962 lbs. per hour of HAPs, and least for CI engines, which emit 0.0359 lbs. per hour. In estimating the emission factors, test data from the Emissions Database from engines rated at greater than 500 hp, operating at all loads, were used.

Table 3-1. HAP Emissions Factors by Engine Configuration (lbs/hour)[a]

Engine Configuration	Emissions Factor (lbs/hour)
2SLB	0.962
4SLB	0.887
4SRB	0.0707
CI	0.0359

Source: Alpha Gamma Technologies, Inc.; Memorandum to Sims Roy, U.S. EPA; National Impacts Associated with Reciprocating Internal Combustion Engines; January, 2002a.

[a] The HAP emissions factors presented are the sum of the factors for formaldehyde, acetaldehyde, acrolein, and methanol.

3.3 CONTROL COSTS

The primary method identified by EPA for controlling emissions from 2SLB, 4SLB, and CI engines is the use of oxidation catalyst systems. However, few existing 2SLB, 4SLB, and CI engines currently use these systems to control their emissions. Less than 1 percent of 2SLB and CI engines are controlled, and only about 3 percent of 4SLB engines are controlled. All of these numbers are below the criteria for a MACT floor in each subcategory, so the MACT floor in these categories was considered to be no control. An above-the-floor MACT option of requiring oxidation catalyst systems was considered for these subcategories of engines, but it was determined that the incremental cost of this alternative would be excessive (EPA, 2000a).

Unlike the situation for the other engine configurations, the average of the top 12 percent of existing 4SRB stationary RICE sources control emissions. The method typically used to control emissions from 4SRB engines is known as non-selective catalytic reduction (NSCR). Because the average of the top 12 percent of existing engines in this category are controlled, the MACT floor for existing 4SRB engines is considered to be the level of HAP emissions reduction achieved by using NSCR systems. Although the percentage of existing 2SLB, 4SLB, and CI engines that are controlled with oxidation catalyst systems is not high enough to mandate a MACT floor requiring control for existing units, there are stationary RICE units operating with these systems in each of these subcategories. Therefore, the MACT floor for new sources in these subcategories is defined as the level of HAP emissions control achieved using oxidation catalyst systems. For new 4SRB engines, the MACT floor is the same as for existing engines. The required control for new 4SRB engines is the level of HAP emissions reduction achieved using NSCR systems (EPA, 2000).

Each unit in the Inventory Database was grouped into one of 12 categories, or model types, based on its engine configuration, horsepower, and fuel type. For each of those model types, the annualized cost of installing pollution control equipment to achieve the floor level of control and the associated administrative, operating, monitoring, and maintenance costs for that equipment were estimated based on information collected from catalyst vendors. First, the total direct and indirect capital costs were estimated as follows. Data on equipment costs (EC) for oxidation catalysts and NSCR for 26 model engines were collected from Engelhard Corporation and Miratech Corporation (the two firms surveyed that provided cost estimates). Because these costs did not include instrumentation, tax, freight, or installation, purchased equipment costs (PEC) were calculated as 118 percent of EC. Direct installation costs (DIC) were then estimated as 30 percent of PEC. The direct capital costs are equal to PEC plus DIC. The indirect capital costs were estimated to be 31 percent of PEC to account for indirect installation costs (e.g., engineering, construction and field expenses, contractor fees, start-up, a performance test, and contingencies). Thus, total capital costs (TCC) are estimated to equal about 1.9 times as much as the equipment costs, i.e., TCC = EC(1.18)(1.3) + EC(1.18)(1.31) = EC(1.9) (Alpha Gamma, 2001b).

To calculate the annualized control costs for each model engine, the direct and indirect annualized costs were calculated. Direct annual costs (DCC) were calculated as $71.30 plus $5/hp for maintenance based on information from vendors. Indirect annualized costs were estimated as 60 percent of maintenance costs for overhead plus 4 percent of TCC for property tax, insurance, and administrative charges plus the annualized capital costs based on an interest rate of 7 percent amortized over 10 years (annualized cost = $\frac{i(1+i)^n}{(1+i)^n - 1}\mathrm{TCC}$, where i is the interest rate and n is the equipment life). The annualized direct and indirect costs were then summed to estimate total annualized compliance costs (Alpha Gamma, 2001b).

For example, the 600 hp Clark RA6 2SLB has a control equipment cost of $7,000 according to the vendor providing the information. The total estimated capital cost to control emissions from this engine model is then 1.9 times $7,000, or $13,300. Annualizing this capital cost over 10 years at 7 percent yields an annualized capital cost of $1,894. Annual maintenance costs for this engine are $71.30 plus $5 times 600 hp, which comes to $3,071. Overhead on the maintenance costs are 60 percent of $3,071, or $1,843. Finally, annual costs for tax, insurance, and administrative charges are estimated to be 4 percent of the total capital costs ($13,300), which is approximately $532. Overall, annualized control costs for this type of engine are estimated to be $7,339. Table 3-2 presents the annualized control costs estimated for each of the engine models with available information.

The average annualized control cost per hp was then calculated for 2SLB, 4SLB, 4SRB, and CI engines by averaging the estimated annualized control cost per hp across three to five sample engines in each category, as shown in Table 3-2. Based on the engines included in the sample, the average annualized control cost is approximately $12/hp for 2SLB, $11/hp for 4SLB, $14/hp for 4SRB, and $11/hp for CI engines (Alpha Gamma, 2002a).

Table 3-2. Control Costs Associated with Model Engines

Model Engines	HP Rating	Capital Control Cost per Model Engine ($)	Annual Control Cost per Model Engine ($/yr)	Capital Control Cost per Model Engine ($ per HP)	Annual Control Cost per Model Engine ($ per HP/yr)
Clark RA6	600	13,299	7,339	22	12
Cooper Bessemer GMV10	1100	27,072	13,851	25	13
Cooper Bessemer GMV10TC	1350	30,777	16,527	23	12
Cooper Bessemer 10V250	3800	72,003	43,646	19	11
Worthington ML20	7500	121,112	82,202	16	11
2SLB Average:				**21**	**12**
Caterpillar 3512	1000	14,344	10,730	14	11
Caterpillar 3512	1220	21,325	13,763	17	11
Waukesha 7042 GL	1478	28,497	17,135	19	12
Cooper Bessemer LSV16G	5200	84,352	57,098	16	11
4SLB Average:				**17**	**11**
Waukesha F3521 GSI	738	27,833	11,094	38	15
Waukesha 7042 G	1024	32,012	14,144	31	14
Waukesha L7042 GSI	1478	40,690	19,532	28	13
4SRB Average:				**32**	**14**
Detroit 16V71	510	12,102	6,401	24	13
Caterpillar D399	750	11,399	8,193	15	11
Detroit 12V92	818	13,964	9,205	17	11
Cummins KTA50	1850	31,775	20,709	17	11
Detroit 16V149	1965	22,399	19,919	11	10
CI Average:				**17**	**11**

Source: Alpha-Gamma Technologies, Inc.; Memorandum to Sims Roy, U.S. EPA; National Impacts Associated with Reciprocating Internal Combustion Engines; January, 2002a.

These estimated costs per hp were then used to estimate the annualized control costs for each of the twelve model engine categories (see Table 3-3). For each model engine, the costs were calculated by multiplying the average cost per hp for the appropriate engine configuration by the midpoint of the horsepower range for that model. For instance, the estimated annualized control cost for a 2SLB engine between 500 and 1,000 hp is 750 hp * $12/hp, which is equal to $9,000.

In addition to the annualized control costs for RICE, there are monitoring costs associated with the proposed rule. Costs for several monitoring options were developed for each of the engine subcategories. The most appropriate method of monitoring was selected for each of the twelve model engine categories based on cost-effectiveness considerations and the potential emissions that could result from poorly performing emission controls. Tables 3-4 and 3-5 present the estimated annualized costs of monitoring for each of the options considered and the option chosen for each model engine category, respectively.

The total annualized compliance costs and monitoring costs calculated for each engine model were used to estimate costs per engine for each of the 12 model unit categories. The total annualized cost of control and monitoring for these units ranges between $14,209 and $148,800. Table 3-6 lists the model types, characteristics, and total costs for each of the 12 unit categories. All affected engines that have capacities between 500 and 1,000 hp have estimated costs less than $17,000 per year. Affected engines that have capacities between 1,000 and 5,000 hp have control and monitoring costs between $38,959 and $48,496 per year. Affected engines with capacities greater than 5,000 hp have annualized control and monitoring costs greater than $125,000 per year. Based on the proportion of each model number identified in the Inventory Database, the mean cost expected per affected new engine is $34,366 and the median is $38,959. The unit-level cost elements were then summed to determine costs at the facility- and parent firm-levels.

Table 3-3. Control Costs Associated with Existing and New RICE

Engine Subcategory	HP Range[a]	Total # Engines Affected (2005)[b]	Average HP	Control Cost per Engine[c] ($/engine)	Annualized Control Cost per Engine[c] ($/yr)
Existing Engines[d]					
4SRB Stationary RICE	500–1,000	3,353	750	24,000	10,500
	1,000–5,000	1,215	3000	96,000	42,000
	5,000–10,000	5	7,500	240,000	105,000
New Engines[d]					
2SLB Stationary RICE	500–1,000	500	750	15,750	9,000
	1,000–5,000	0	3000	63,000[e]	36,000[e]
	5,000–10,000	0	7,500	157,500[e]	90,000[e]
4SLB Stationary RICE	500–1,000	2,124	750	12,750	8,250
	1,000–5,000	3,412	3000	51,000	33,000
	5,000–10,000	12	7,500	127,500	82,500
4SRB Stationary RICE	500–1,000	1,858	750	24,000	10,500
	1,000–5,000	2,417	3,000	96,000	42,000
	5,000–10,000	8	7,500	240,000	105,000
CI Stationary RICE	500–1,000	5,987	750	12,750	8,250
	1,000–5,000	3,991	3,000	51,000	33,000
	5,000–10,000	0	7,500	127,500[d]	82,500[d]

Source: Alpha-Gamma Technologies, Inc.; Memorandum to Sims Roy, U.S. EPA; National Impacts Associated with Reciprocating Internal Combustion Engines; January, 2002a.

[a] There are no existing stationary RICE greater than 10,000 HP, and the presented population excludes emergency power units and engines 500 HP or less.

[b] Control costs are calculated using the average HP for the HP range in question, multiplied times the average control cost in $ per HP, obtained from Table 3-2.

[c] The only engines affected are those existing 4SRB and new RICE that are or will be located at major sources. The number of affected sources was rounded to the nearest integer in this table for presentation, but fractional engines were used in calculations.

[d] It was estimated that 3 percent of 4SLB and 27 percent of 4SRB engines would be controlled in the absence of the regulation (no 2SLB or CI engines are projected to be controlled). These engines would not incur control costs under the RICE NESHAP.

[e] These values are the estimated annualized control costs that would be incurred if any units in these subcategories were to comply with the RICE NESHAP. However, there are projected to be no new engines in these subcategories by 2005.

Table 3-4. Costs of Monitoring for RICE Subcategories

Engine Subcategory	Monitoring Option[a]	Monitoring Capital Cost ($/engine)	Total Annualized Monitoring Cost ($/engine)
2SLB Stationary RICE	Option 1	208,900	58,800
	Option 2	5,699	21,618
	Option 3	13,479	5,959
	Option 4	13,479	3,938
4SLB Stationary RICE	Option 1	208,900	58,800
	Option 2	5,699	21,618
	Option 3	13,479	5,959
	Option 4	13,479	3,938
4SRB Stationary RICE	Option 5	5,699	21,618
	Option 6	5,699	6,496
CI Stationary RICE	Option 1	208,900	58,800
	Option 2	5,699	21,618
	Option 3	13,479	5,959
	Option 4	13,479	3,938

Source: Alpha-Gamma Technologies, Inc.; Memorandum to Sims Roy, U.S. EPA; National Impacts Associated with Reciprocating Internal Combustion Engines; January, 2002a.

[a] Monitoring costs are independent of engine horsepower.

Option 1: CEM for CO.
Option 2: Semi-annual stack testing for CO using Method 10A and continuous parametric monitoring (catalyst pressure drop and temperature).
Option 3: Quarterly stack testing using portable CO monitor (ASTM D6522-00) and continuous parametric monitoring (catalyst pressure and temperature).
Option 4: Initial stack testing using portable CO monitor (ASTM D6522-00) and continuous parametric monitoring (catalyst pressure and temperature).
Option 5: Annual stack testing for formaldehyde (FTIR or CARB 430) and continuous parametric monitoring (catalyst pressure and temperature).
Option 6: Initial stack testing for formaldehyde (FTIR or CARB 430) and continuous parametric monitoring (catalyst pressure and temperature).

Table 3-5. Monitoring Option Applied to RICE Model Engine Categories

Engine Subcategory	HP Range	Monitoring Option Selected	Monitoring Capital Cost ($/engine)	Total Annualized Monitoring Cost ($/engine)
2SLB Stationary RICE	500–1,000	Option 3	13,479	5,959
	1,000–5,000	Option 3	13,479	5,959
	5,000–10,000	Option 1	208,900	58,800
4SLB Stationary RICE	500–1,000	Option 3	13,479	5,959
	1,000–5,000	Option 3	13,479[a]	5,959[a]
	5,000–10,000	Option 1	208,900[a]	58,800[a]
4SRB Stationary RICE	500–1,000	Option 6	5,699	6,496
	1,000–5,000	Option 6	5,699	6,496
	5,000–10,000	Option 5	5,699	21,618
CI Stationary RICE	500–1,000	Option 3	13,479	5,959
	1,000–5,000	Option 3	13,479	5,959
	5,000–10,000	Option 1	208,900[a]	58,800[a]

[a] These values are the estimated monitoring costs that would be incurred if any units in these subcategories were to comply with the RICE NESHAP. However, there are projected to be no new engines in these subcategories by 2005.

Option 1: CEM for CO.
Option 2: Semi-annual stack testing for CO using Method 10A and continuous parametric monitoring (catalyst pressure drop and temperature).
Option 3: Quarterly stack testing using portable CO monitor (ASTM D6522-00) and continuous parametric monitoring (catalyst pressure and temperature).
Option 4: Initial stack testing using portable CO monitor (ASTM D6522-00) and continuous parametric monitoring (catalyst pressure and temperature).
Option 5: Annual stack testing for formaldehyde (FTIR or CARB 430) and continuous parametric monitoring (catalyst pressure and temperature).
Option 6: Initial stack testing for formaldehyde (FTIR or CARB 430) and continuous parametric monitoring (catalyst pressure and temperature).

Table 3-6. Total Annualized Control Cost for Affected Units

Model Number	Engine Configuration	Fuel Type	Hp Range	Annualized Control Cost	Annual Monitoring Cost	Average Total Annualized Cost
1	2SLB	Natural gas	500 to 1,000	$9,000	$5,959	$14,959
2	2SLB	Natural gas	1,000 to 5,000	$36,000	$5,959	$41,959
3	2SLB	Natural gas	5,000 to 10,000	$90,000	$58,800	$148,800
4	4SLB	Natural gas	500 to 1,000	$8,250	$5,959	$14,209
5	4SLB	Natural gas	1,000 to 5,000	$33,000	$5,959	$38,959
6	4SLB	Natural gas	5,000 to 10,000	$82,500	$58,800	$141,300
7	4SRB	Natural gas	500 to 1,000	$10,500	$6,496	$16,996
8	4SRB	Natural gas	1,000 to 5,000	$42,000	$6,496	$48,496
9	4SRB	Natural gas	5,000 to 10,000	$105,000	$21,618	$126,618
10	CI	Diesel	500 to 1,000	$8,250	$5,959	$14,209
11	CI	Diesel	1,000 to 5,000	$33,000	$5,959	$38,959
12	CI	Diesel	5,000 to 10,000	$82,500	$58,800	$141,300

Because the baseline emissions per engine, percentage reduction in emissions that will be achieved under the proposed rule, and the annualized control cost differ between engine models, the cost-effectiveness of HAP reductions will also differ between engine model categories. Table 3-7 presents estimates of the cost-effectiveness for each RICE model engine category affected by the RICE NESHAP. Controlling emissions from 4SLB is the most cost-effectiveness, whereas reducing emissions from CI engines is the least cost-effective. In each subcategory, emission reductions are achieved at the lowest cost per ton of HAP in the 1,000 to 5,000 hp engine size range.

Table 3-7. Cost Effectiveness for Each Model Engine Category

	Total Cost per Engine($/year)	HAP Emission Reduction per Engine (ton/year)	Cost Effectiveness ($/ton)
New 2SLB			
500–1,000 HP	14,959	0.71	21,039
1,000–5,000 HP	41,959	2.84	14,754
5,000–10,000 HP	148,800	7.11	20,928
New 4SLB			
500–1,000 HP	14,209	1.08	13,189
1,000–5,000 HP	38,959	4.31	9,040[a]
5,000–10,000 HP	141,300	10.77	13,115[a]
New and Existing 4SRB			
500–1,000 HP	16,996	0.23	72,807
1,000–5,000 HP	48,496	0.93	51,937
5,000–10,000 HP	126,618	2.33	54,241
New CI			
500–1,000 HP	14,209	0.05	314,674
1,000–5,000 HP	38,959	0.18	215,697
5,000–10,000 HP	141,300	0.45	312,924[a]

Source: Calculations by Alpha-Gamma Technologies based on information contained in Alpha-Gamma Technologies, Inc.; Memorandum to Sims Roy, U.S. EPA; National Impacts Associated with Reciprocating Internal Combustion Engines; January, 2002a.

[a] These values are the estimated cost-effectiveness that would be achieved if any of these units were to comply with the RICE NESHAP. However, there are projected to be no new engines in these subcategories by 2005.

3.4 PROFILE OF RICE UNITS AND FACILITIES IN INVENTORY DATABASE

3.4.1 *Affected Units*

Engines in the Inventory Database range in capacity from 500 to 8,000 hp. Despite the presence of units with horsepower capacity of 5,000 or more, the vast majority of units are less than 1,500 hp (see Figure 3-1). About 80 percent of the Inventory units, 2,088 engines, have capacities less than 1,500 hp. More than half of those engines have less than 1,000 hp. Only 557 units are greater than 1,500 hp.

About two-thirds of the units in the Inventory Database are described as lean-burn units (see Figure 3-2). All of the rich-burn units are four-stroke; the lean-burn units are split fairly evenly between two-stroke and four-stroke configurations. Also, 95 percent of the units use natural gas for fuel (only about 5 percent are CI units).

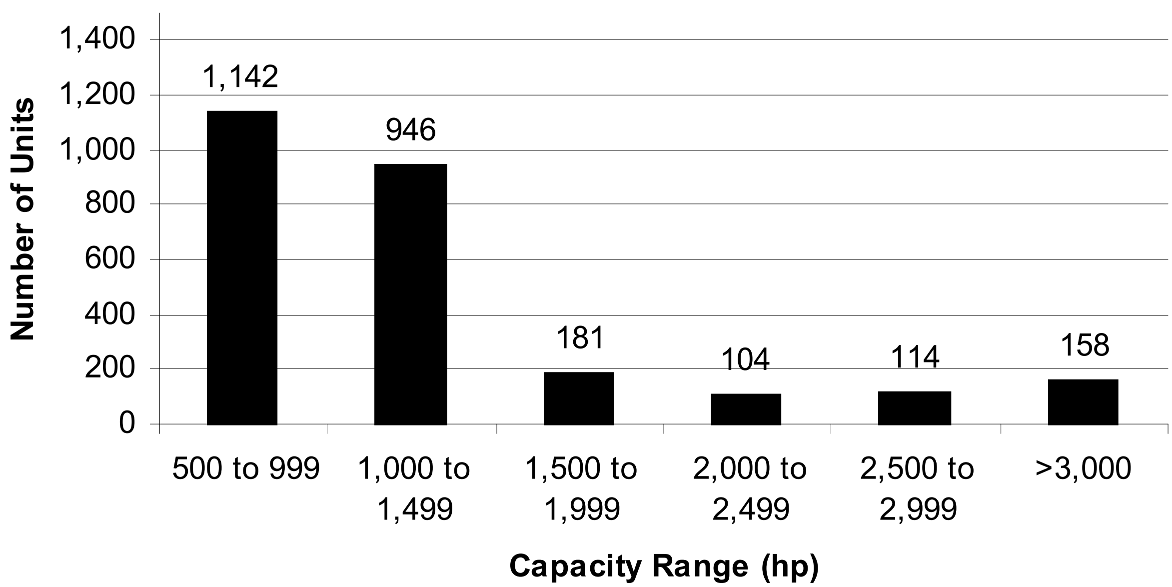

Figure 3-1. Capacity Ranges for Engines in the Inventory Database

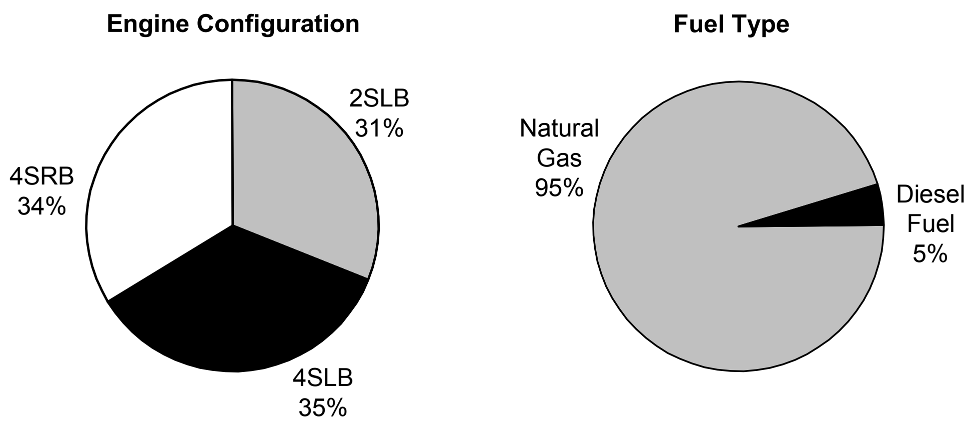

Figure 3-2. Characteristics of Engines in Inventory Database

3.4.2 *Affected Facilities*

The 2,645 units in the Inventory Database for which sufficient identifying information is available are located at 834 facilities. Table 3-8 presents the distribution of units and facilities by industry grouping. Most of the Inventory Database units are concentrated in two industries: oil and gas extraction and pipeline transportation. These units are for the most part located at compression stations on natural gas pipelines or at oil and gas fields and plants. The only other industries with relatively sizable numbers of units at the three-digit NAICS code level are the mining (except oil and gas) industry (NAICS 212), hospitals (NAICS 622), and electric utilities (NAICS 221).

3.5 PROJECTED GROWTH OF RICE

The Agency estimates that, without the rule, the United States will have 20,309 new RICE engines with horsepower greater than 500 (that are not used as backup/emergency units) by 2005 (see Table 2-5). These estimates are based on the expected growth in the number of engines in each of the 12 model categories listed in Table 3-9. All growth estimates are based on information provided by the EPA Office of Mobile Sources (now the Office of Transportation

Table 3-8. Number of Units With Assigned Model Numbers, the Number of Facilities at Which They are Located, and the Average Number of Units per Facility, by Industry in the Inventory Database[a]

NAICS	Industry Description	Number of Units	Number of Facilities	Average Number of Units Per Facility
112	Animal Production	1	1	1.0
211	Oil and Gas Extraction	1,148	312	3.7
212	Mining (Except Oil and Gas)	33	28	1.2
221	Utilities	35	15	2.3
234	Heavy Construction	1	1	1.0
311	Food Manufacturing	15	4	3.8
312	Beverage and Tobacco Product Manufacturing	9	1	9.0
322	Paper Manufacturing	1	1	1.0
324	Petroleum and Coal Products Manufacturing	11	7	1.6
325	Chemical Manufacturing	16	4	4.0
326	Plastics and Rubber Products Manufacturing	1	1	1.0
327	Nonmetallic Mineral Product Manufacturing	1	1	1.0
331	Primary Metal Manufacturing	3	1	3.0
421	Wholesale Trade, Durable Goods	1	1	1.0
441	Motor Vehicle and Parts Dealers	4	1	4.0
486	Pipeline Transportation	1,282	424	3.0
488	Support Activities for Transportation	1	1	1.0
524	Insurance Carriers and Related Activities	5	3	1.7
531	Real Estate	1	1	1.0
541	Professional, Scientific, and Technical Services	13	1	13.0
562	Waste management and Remediation Services	2	1	2.0
611	Educational Services	1	1	1.0
622	Hospitals	36	20	1.8
922	Justice, Public Order, and Safety Activities	4	1	4.0
Unknown	Industry Classification Unknown	20	2	10.0
Total		2,645	834	3.1

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

[a] Although there are a total of 26,832 engines in the Inventory Database, only 2,645 of these units are potentially affected by the rule (i.e., they are greater than 500 hp and are not emergency/backup units) and have enough information to assign a model number. These are the units in the Inventory Database that serve as the basis for assigning compliance costs by industry.

Table 3-9. Population Estimates of Affected RICE Units, 2005[a]

Model Number	Engine Configuration	Units in Inventory Database with Model #[b]	Total Existing Affected Units[c]	Existing Affected Uncontrolled Units	Total 5-year Growth in Affected Units	5-year Growth in Affected Uncontrolled Units[d]	Total Affected Units (2,005)
1	2SLB	259	0	0	200	200	200
2	2SLB	500	0	0	0	0	0
3	2SLB	57	0	0	0	0	0
4	4SLB	170	0	0	850	824	850
5	4SLB	608	0	0	1,365	1,324	1,365
6	4SLB	37	0	0	5	5	5
7	4SRB	650	1,341	979	743	542	2,084
8	4SRB	238	486	355	967	706	1,453
9	4SRB	1	2	1	3	2	5
10	CI	63	0	0	2,395	2,395	2,395
11	CI	60	0	0	1,596	1,596	1,596
12	CI	2	0	0	0	0	0
Total		2,645	1,829	1,335	8,124	7,594	9,953

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

[a] The only RICE directly affected by the rule are those existing 4SRB and new RICE that are or will be located at major sources. The number of units was rounded to the nearest integer in this table for presentation, but fractional engines were used in calculations.

[b] Only the engines in the Inventory Database with sufficient information to assign a model number were used in estimating costs by industry.

[c] The only existing engines affected by this rule are 4SRB engines, some of which are already controlled in the absence of this rule. Monitoring costs due to the rule apply to all of the 4SRB engines, even those already controlled.

[d] It is assumed that 27 percent of new 4SRB and 3 percent of new 4SLB engines would be controlled in the absence of this regulation. Therefore, the costs of controls for these engines are not included in the total cost of the regulation. However, the monitoring costs incurred by all of these engines due to the rule are included in calculating the total cost.

and Air Quality) regarding estimated five year sales volume for engines, which was derived from the Power Systems Research database, and confidential sales projection information provided to EPA by engine manufacturers. However, not all of these engines will be affected by the RICE NESHAP because it only applies to RICE located at major sources. The percentage of sources that are major in the natural gas prime mover (60 percent), crude petroleum and natural gas (33 percent), and electric services (100 percent) sectors were estimated by obtaining information from representative industry organizations (Alpha Gamma, 2001a). Estimates for the percentage of engines owned by the Department of Defense that are located at major sources (31 percent) were obtained from a representative of the Naval Facilities Engineering Service Center and EPA assumed that only 25 percent of all other engines would be located at major sources (Alpha Gamma, 2001a).

EPA calculated the overall percentage of existing engines at major sources based on the percentage of existing engines owned by each of these five segments (Department of Defense, 13 percent; natural gas prime movers, 25 percent; crude petroleum and natural gas, 33 percent; electric services, 5 percent; and other miscellaneous, 24 percent) and the percentage of those existing engines estimated to be major sources. Using this method, the percentage of RICE located at major sources is estimated to be approximately 40 percent (Alpha Gamma, 2001a). Based on an assumption that the proportion of existing engines located at major sources is a good approximation for the percentage of future engines that will be located at major sources, EPA assumed that only 40 percent of RICE engines subject to the proposed rule that will be installed in the future will incur compliance costs.

Thus, the Agency estimates that the U.S. will have 8,124 new IC engines with horsepower greater than 500 by the end of 2005 that will be affected by the rule (see Table 2-5) based on the assumption that 40 percent of new RICE would be located at major sources. Table 3-9 lists several unit counts: units in the Inventory Database with assigned model numbers, existing affected units, and projected unit growth over 5 years. The latter two categories are also broken out by the total number of units and the number of units that would have been controlled regardless of the rule.

Existing 2SLB engines (model numbers 1, 2, and 3) are not affected by the rule. As new 2SLB units come online, however, they will be required to install the requisite control equipment and operators will have to adhere to monitoring requirements. It is estimated that 200 new 2SLB engines of greater than 500 hp will have come into operation at major sources by the end of 2005, none of which are expected to be greater than 1,000 hp.

Existing 4SLB engines (model numbers 4, 5, and 6) are also not affected by this rule. In the absence of this rule, it is expected that 3 percent of new units would come online controlled in the future based on the percentage of units currently controlled (Alpha Gamma, 2002a). Therefore, only the remaining 97 percent of units located at major sources (2,152 of 2,219 units) will have control costs associated with the rule. The cost of controlling the additional remaining 3 percent was not included in the rule's cost because it would have been borne by industry regardless of the rule; the rule will not affect those business decisions. However, all 2,219 new 4SLB engines located at major sources will incur monitoring costs. It is expected that very few of these units will be greater than 5,000 hp.

The only existing engines that are affected by the rule are 4SRB engines (model numbers 7, 8, and 9). Those engines that are located at major sources and not already controlled, 1,335 units, will have to install control equipment. All existing 4SRB engines located at major sources (1,829 units) must comply with the monitoring component of the rule. For new sources, the Agency estimates that 27 percent (463 units) would come online controlled without the rule based on the current population of 4SRB engines (Alpha Gamma, 2000). Thus, control costs for these units are not included in the total cost of the rule. However, all 1,713 units projected to enter into operation at major sources by the end of 2005 will incur monitoring costs. Most existing units are less than 1,000 hp, but the majority of new units are expected to be between 1,000 and 5,000 hp.

Similar to 2SLB and 4SLB engines, only new CI engines (model numbers 10, 11, and 12) will be affected by this rule. Existing CI engines do not have to add any controls. None of these engines are projected to be controlled in the absence of regulation. Therefore, all 3,991 units estimated to enter into operation at major sources by the end of 2005 will be subject to both control and monitoring costs under the regulation. About 60 percent of these units are expected to be under 1,000 hp; no units are expected to be greater than 5,000 hp.

3.5.1 *Growth Estimates by Industry*

Although growth estimates by engine configuration and horsepower are available, estimates of the growth in the number of units by industry are not. To assess the distribution of the engines estimated to be operating in 2005 across industries, it was assumed that the distribution of each model engine number across industries for the units in the Inventory Database with assigned model numbers is representative of the distribution of future units across industries. This distribution was then used to estimate the number of affected engines that would be added in each industry by 2005.

3.5.1.1 *Mapping SIC Codes to NAICS Codes*

Although the economic analysis was originally conducted based on SIC-level costs, the SIC information included with affected unit and facility records in the Inventory Database was later complemented with the appropriate NAICS code to reflect the change in industry classification that has occurred in recent years. The original 4-digit SIC codes for these units and facilities were mapped to corresponding 3-digit NAICS code (3-digit NAICS codes are the functional equivalent of 2-digit SIC codes, the highest level of detail often shown in economic analyses). The 1997 NAICS and 1987 SIC Correspondence Tables prepared by the Bureau of the Census were used to determine the matching NAICS codes.[2] The process of mapping SIC codes to NAICS codes was relatively straightforward because, although there are 2,645 RICE units in the Inventory Database with sufficient information to assign model engine numbers, three 4-digit SIC codes accounted for more than 91 percent of the units:

- 1,268 units in SIC 4922 (“Natural Gas Transmission”) were mapped to NAICS 486 (“Pipeline Transportation”).
- 601 units in SIC 1321 (“Natural Gas Liquids”) were mapped to NAICS 211 (“Oil and Gas Extraction”).
- 543 units in SIC 1311 (“Crude Petroleum and Natural Gas”) were mapped to NAICS 211 (“Oil and Gas Extraction”).

[2]The 1997 NAICS and 1987 SIC Correspondence Tables can be viewed on the Bureau of the Census website at http://www.census.gov/epcd/www/naicstab.htm.

Overall, there were 47 different 4-digit SIC codes in the database, with all of them having well-defined corresponding 3-digit NAICS codes. There were no instances where a 4-digit SIC code was divided into two separate NAICS codes. Thus, the assignment of costs at the NAICS level yields very similar costs by industry to those achieved using SIC codes (as well as very similar results), but is consistent with the recent movement towards using NAICS codes in regulatory analyses.

3.5.1.2 *Data Extrapolation to Projected National Unit Estimates by Industry*

The Inventory Database contains information on type of engine (e.g., 2SLB, 4SLB, 4SRB, CI), engine size (hp), and SIC code, among other data. As discussed above, a column containing the 3-digit NAICS code was added by mapping SIC codes to their corresponding NAICS classifications. To develop national economic impact estimates by industry based on the subset of units with sufficient data included in the Inventory Database, national unit population estimates (Alpha Gamma, 2002a) for both existing and new sources in 2005 were used. However, these estimates were provided for 12 model engines (defined by engine type and size), not by industry. Therefore, the industry classification of units in the Inventory Database was used to estimate the distribution of the RICE population estimates across industries.

The projected distribution of engines by industry was based on the current distribution in the Inventory Database. For example, it was estimated that 500 units of engine model 1 (2SLB, 500 to 1,000 hp) will be added by 2005 (Alpha Gamma, 2002a), with 200 units located at major sources. There are 259 units identified as model 1 in the Inventory Database. Therefore, for each model 1 unit that is included in the database for a particular industry, it was assumed that 1.931 model 1 units (i.e., 500/259) would be added in that industry by 2005. In other words, it was assumed that the current distribution of each model engine across industries, as reported in the Inventory Database, is representative of the future distribution of each model engine category across industries. For instance, the database included 122 model 1 engines in NAICS 486, 131 in NAICS 211, 2 in NAICS 311, and 4 in NAICS 541. Therefore, the projected distribution of the 500 model 1 engines projected to be added by 2005 was approximately 235.6 in NAICS 486, 253.0 in NAICS 211, 3.9 in NAICS 311, and 7.7 in NAICS 541. It was assumed that 40 percent of the engines in each NAICS code would be located at major sources and would be subject to the rule.

NAICS codes 211 and 486 represent over 91 percent of the units in the Inventory Database, but only 60 percent of the estimated affected population in 2005. This is due to the large increase in CI units projected and the extremely small share of CI units that are in these two NAICS codes based on the Inventory Database. For example, there are 63 engines that are model 10 (CI, 500 to 1,000 hp) in the database, but only 1 (1.6 percent) is in NAICS 211 and 3 (4.8 percent) are in NAICS 486. It was projected that a total of 2,395 affected model 10 engines will be added by 2005 (24 percent of total affected engines) (Alpha Gamma, 2002a), but very few are projected to be in NAICS codes 211 or 486. Overall, 49 percent of new affected units are projected to be CI units (3,991 CI units/8,124 total projected units) with NAICS codes 211 and 486 accounting for only 0.8 percent and 4.8 percent, respectively.

The total number of affected units estimated to exist in 2005 by industry is presented in Table 3-10. The third column lists the number of units in the Inventory Database with assigned model numbers (the units that served as the basis for cost estimates by industry). The fourth column presents the estimated population of affected engines projected by industry for 2005.

Table 3-10. Affected RICE Population and Engineering Costs by NAICS Code, 2005

NAICS	Industry Description	Number of Units in Inventory Database with Model #[a]	Estimated 2005 Affected Populationb	Annualized Engineering Costs (1998$)
112	Animal Production	1	3	45,411
211	Oil and Gas Extraction	1,148	2,875	71,102,348
212	Mining (Except Oil and Gas)	33	1,032	20,401,095
221	Utilities	35	859	25,707,611
234	Heavy Construction	1	—	—
311	Food Manufacturing	15	63	1,971,951
312	Beverage and Tobacco Product Manufacturing	9	31	629,936
322	Paper Manufacturing	1	27	1,036,633
324	Petroleum and Coal Products Manufacturing	11	148	2,811,969
325	Chemical Manufacturing	16	173	4,469,266
326	Plastics and Rubber Products Manufacturing	1	27	1,036,633
327	Nonmetallic Mineral Product Manufacturing	1	38	540,111
331	Primary Metal Manufacturing	3	7	255,691
421	Wholesale Trade, Durable Goods	1	38	540,111
441	Motor Vehicle and Parts Dealers	4	13	181,645
486	Pipeline Transportation	1,282	3,110	80,076,833
488	Support Activities for Transportation	1	3	45,411
524	Insurance Carriers and Related Activities	5	86	3,200,721
531	Real Estate	1	38	540,111
541	Professional, Scientific, and Technical Services	13	9	273,032
562	Waste management and Remediation Services	2	53	2,073,266
611	Educational Services	1	27	1,036,633
622	Hospitals	36	1,163	26,397,114
922	Justice, Public Order, and Safety Activities	4	129	3,153,487
Unknown	Industry Classification Unknown	20	3	45,411
Total		**2,645**	**9,953**	**247,572,429**

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

[a] Although there are a total of 26,832 engines in the Inventory Database, only 2,645 of these units are potentially affected by the rule (i.e., they are greater than 500 hp and are not emergency/backup units) and have enough information to assign a model number. These are the units in the Inventory Database that serve as the basis for assigning compliance costs by industry.

3.5.2 *Engineering Compliance Costs*

Based on the projected distribution of each model engine type across industries, total annualized costs were estimated by multiplying the projected number of affected engines in each model engine category by the annualized compliance cost per engine for that model engine type. This calculation was performed for each industry as follows:

$$(3.1)\quad TACC_j = \sum_{i=1}^{12} TACC_{ij} = \sum_{i=1}^{12} \left(\frac{n_{ij}}{\sum_{j=1}^{25} n_{ij}} * \left[AFF_{CON,i} * ACC_{CON,i} + AFF_{UNC,i} * ACC_{UNC,i} \right] \right)$$

where $TACC_j$ is the total annualized compliance cost for industry j (there are 25 industry categories in the model), i = 1,...,12 represents the model engine categories, n_{ij} is the number of engines of model type i used in industry j that are included in the Inventory Database and have sufficient information available to assign them a model number, $AFF_{CON,i}$ is the number of affected engines of model type i projected to exist in 2005 that would be controlled in the absence of the RICE NESHAP, $ACC_{CON,i}$ represents the annualized compliance cost for a single engine of model type i that would be controlled in the absence of the RICE NESHAP[3], and $AFF_{UNC,i}$ and $ACC_{UNC,i}$ are the measures for RICE that would be uncontrolled in the absence of the NESHAP corresponding to $AFF_{CON,i}$ and $ACC_{CON,i}$. As an example of the calculation of total annualized costs for an industry, the calculations used in estimating the total annualized costs of the RICE NESHAP for NAICS 211 are described below.

3.5.2.1 *Sample Industry Cost Calculation: NAICS 211*

RICE in the Inventory Database that were identified as being used in SIC codes 1311 (Oil and Gas Extraction) and 1321 (Natural Gas Liquids) were mapped into NAICS 211. In the Inventory Database, there are 1,148 units identified that were placed in this NAICS code. They are distributed among model engine types as shown in Table 3-11 (column 2). Compliance costs

[3]It was estimated that 0 percent of 2SLB, 3 percent of 4SLB, 27 percent of 4SRB, and 0 percent of CI engines would be controlled in the absence of the RICE NESHAP (Alpha Gamma, 2002a). The engines that would be controlled in the absence of the NESHAP still have compliance costs associated with the rule because they are subject to monitoring requirements.

for NAICS 211 were estimated by applying equation (3.1) to the data contained in columns 1 through 4 of Table 3-11.

For example, the total annualized compliance cost for NAICS 211 to upgrade model 1 engines was calculated as follows. For NAICS 211, $n_{1,211}$ = 131 and $\sum_{j=1}^{25} n_{1,j}$ = 259. Because there are projected to be no model 1 engines that would be controlled in the absence of this regulation, $AFF_{CON,1}$ is equal to zero. For model 1 engines that would be uncontrolled in the baseline, the annualized cost per engine, ACC_1, was estimated to be $14,959 (Alpha Gamma, 2002a). The total number of affected model 1 engines that would be uncontrolled in the baseline, $AFF_{UNC,1}$ is estimated to be 200 (see Table 2-5). Thus, the cost to NAICS 211 of controlling model 1 engines, $TACC_{1,211}$, is equal to 131/259*[200*$14,959+0*$5,959], or $1,513,227.

Using similar calculations for each model engine type and summing across all 12 model engine types yields the total projected cost to NAICS 211. That total is estimated to be $71,102,348, as reported in Tables 3-10 and 3-11.

3.5.2.2 *National Engineering Compliance Costs*

Based on the projections in Table 3-10 of the affected RICE population, the engineering control costs of this regulation would be $247.6 million in 2005. These costs are inputs into the market model used in Section 5 to estimate the changes in price and quantity taking place in each affected market as a result of the regulation as well as the social costs of the rule. The magnitude and distribution of the regulatory costs' impact on the economy depend on the relative size of the impact on individual markets (relative shift of the market supply curves) and the behavioral responses of producers and consumers in each market (as measured by the elasticity of supply and the elasticity of demand). To the extent that the projections by engine model are inaccurate, the Inventory Database is not representative of the current distribution of engines, and/or the distribution of future affected engines across industries will differ from the current distribution, the actual costs experienced across industries may differ from those projected. In addition, there are costs for reporting and record keeping totalling $6.1 million that are not included in the economic model.

Table 3-11. Sample Cost Calculation: Estimating Compliance Costs for NAICS 211

Engine Model	Engines in Inventory Database (NAICS 211/ Total)	Projected Number of Affected Engines (2005)[a] (Uncontrolled/ Controlled in Baseline)	Cost Per Affected Engine (Uncontrolled/ Controlled in Baseline)	Projected Cost for NAICS 211 by Model Engine Category
(i)	($n_{i,211}/\Sigma n_{ij}$)	($AFF_{UNC,i}/AFF_{CON,i}$)	($ACC_{UNC,i}/ACC_{CON,i}$)	($TACC_{i,211}$)
1	131/259	200/0	$14,959/$5,959	$1,513,227
2	257/500	0/0	$41,959/$5,959	$0
3	6/57	0/0	$148,800/$58,800	$0
4	66/170	824/25	$14,209/$5,959	$4,605,127
5	184/608	1,324/41	$38,959/$5,959	$15,682,396
6	11/37	5/0	$141,300/$58,800	$198,107
7	349/650	1,522/563	$16,996/$6,496	$15,848,536
8	142/238	1,061/392	$48,496/$6,496	$32,209,416
9	1/1	4/1	$126,618/$21,618	$505,430
10	1/63	2,395/0	$14,209/$5,949	$540,111
11	0/60	1,596/0	$38,959/$5,949	$0
12	0/2	0/0	$141,300/$58,800	$0
Total	1,148/2,645	8,930/1,023	NA	$71,102,348

Note: The number of engines has been rounded to the nearest integer for presentation. However, fractional engines were used in calculations. Thus, applying equation (3.1) using the values in columns 1 through 4 may not yield the exact cost presented in column 5 due to rounding.

4.0 PROFILES OF AFFECTED INDUSTRIES

This section contains profiles of the industries most directly affected by the proposed regulation of RICE units. Most existing engines that would be subject to the regulation are concentrated in two industries, oil and natural gas extraction (NAICS 211) and natural gas pipeline transportation (NAICS 4862). Together, they account for over 90 percent of the engines identified by EPA in the Inventory Database that would fall under this rule. (The remaining units are spread across various industries, most notably mining, hospitals, and various manufacturing industries, such as food manufacturing and chemical manufacturing.) Most new engines that would be affected by this regulation are also projected to be in these industries.

The oil and natural gas industry is divided into five distinct sectors: (1) exploration, (2) production, (3) transportation, (4) refining, and (5) marketing. The NESHAP considers controls on the use of RICE units, which are used in this industry primarily to power compressors used for crude oil and natural gas extraction and natural gas pipeline transportation. Therefore, this section contains background information on the oil and natural gas extraction industry and the natural gas transmission industry to help inform the regulatory process.

4.1 CRUDE PETROLEUM AND NATURAL GAS (NAICS 211)

The crude petroleum and natural gas industry encompasses the oil and gas extraction process from the exploration for oil and natural gas deposits through the transportation of the product from the production site. The primary products of this industry are natural gas, natural gas liquids, and crude petroleum.

4.1.1 *Introduction*

The U.S. is home to half of the major oil and gas companies operating around the globe. Although small firms account for nearly 45 percent of U.S. crude oil and natural gas output, the domestic oil and gas industry is dominated by 20 integrated petroleum and natural gas refiners and producers, such as Exxon Mobil, BP Amoco, and Chevron (Lillis, 1998). Despite the presence of many large global players, the industry experiences a more turbulent business cycle than most other major U.S. industries. Because oil is an international commodity, the U.S. production of crude oil is affected by the world crude oil price, the price of alternative fuels, and existing regulations. Domestic oil production has been falling in recent years. Total U.S. crude oil production is expected to fall to 5.78 million barrels per day in 2000, the lowest annual U.S. crude oil output since 1950 (EIA, 2000a). Because the industry imports 60 percent of the crude oil used as an input into refineries, it is susceptible to fluctuations in crude oil output and prices, which may be influenced by the Organization of Petroleum Exporting Countries (OPEC).[1]

In contrast, natural gas markets in the U.S. are competitive and relatively stable. Domestic natural gas production has been on an upward trend since the mid-1980s. Almost all natural gas used in the U.S. comes from domestic and Canadian sources.

There are four sub- or related industries to NAICS 211 (see Table 4-1):

- NAICS 211111: Crude petroluem and natural gas extraction. Firms in this industry are primarily engaged in (1) the exploration, development and/or the production of petroleum or natural gas from wells in which the hydrocarbons will initially flow or can be produced using normal pumping techniques, or (2) the production of crude petroleum from surface shales or tar sands or from reservoirs in which the hydrocarbons are semisolids. Establishments in this industry operate oil and gas wells on their own account or for others on a contract or fee basis.
- NAICS 211112: Natural gas liquid (NGL) extraction. Firms in this industry are primarily engaged in the recovery of liquid hydrocarbons from oil and gas field

[1]OPEC is a cartel consisting of most of the world's largest petroleum-producing countries that attempts to increase the profits of member countries.

gases. Establishments primarily engaged in sulfur recovery from natural gas are included in this industry.

- NAICS 213111: Drilling oil and gas wells. Firms in this industry are primarily engaged in drilling oil and gas wells for others on a contract or fee basis. This industry includes contractors that specialize in spudding in, drilling in, redrilling, and directional drilling.
- NAICS 213112: Support activities for oil and gas operations. Firms in this industry perform oil and gas field services (except contract drilling) for others, on a contract or fee basis. Services included are exploration (except geophysical surveying and mapping); excavating slush pits and cellars; grading and building foundations at well locations; well surveying; running, cutting, and pulling casings, tubes, and rods; cementing wells; shooting wells; perforating well casings; acidizing and chemically treating wells; and cleaning out, bailing, and swabbing wells.

Table 4-1. Crude Petroleum and Natural Gas Industries Likely to Be Affected by the Regulation

NAICS	Description
211111	Crude Petroleum and Natural Gas Extraction
211112	Natural Gas Liquid Extraction
213111	Drilling Oil and Gas Wells
213112	Support Activities for Oil and Gas Operations

In 1997, more than 6,800 crude oil and natural gas extraction companies (NAICS 211111) generated $75 billion in revenues (see Table 4-2). Revenues for 1997 were approximately 5 percent higher than revenues in 1992, although the number of companies and employees declined 11.5 and 42.5 percent, respectively.

Table 4-2. Summary Statistics, Crude Oil and Natural Gas Extraction and Related Industries

NAICS	Industry	Number of Companies	Number of Establishments	Revenues ($1997 10^3)	Employees
211111	Crude Oil and Natural Gas Extraction				
	1992	7,688	9,391	71,622,600	174,300
	1997	6,802	7,781	75,162,580	100,308
211112	Natural Gas Liquid Extraction				
	1992	108	591	26,979,200	12,000
	1997	89	529	24,828,503	10,549
213111	Drilling Oil and Gas Wells				
	1992	1,698	2,125	3,552,707	47,700
	1997	1,371	1,638	7,317,963	53,865
213112	Support Activities for Oil and Gas Operations				
	1997	6,385	7,068	11,547,563	106,339

Sources: U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Economic Census, Mining Industry Series*. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Mineral Industries, Industry Series*. Washington, DC: U.S. Department of Commerce.

Table 4-2 shows the NGL extraction industry (NAICS 211112) experienced a decline in the number of companies, establishments, and employees between 1992 and 1997. The industry's revenues declined nearly 8.0 percent during this time, from $27 billion per year to $24.8 billion per year.

Revenues for NAICS 213111, drilling oil and gas wells, more than doubled between 1992 and 1997. In 1992, the industry employed 47,700 employees at 1,698 companies and generated $3.6 billion in annual revenues. By the end of 1997, the industry's annual revenues were $7.3 billion, a 106 percent improvement. Although the total number of companies and establishments decreased from 1992 levels, industry employment increased 13 percent to 53,685.

The recent transition from the Standard Industrial Classification (SIC) system to the North American Industrial Classification System (NAICS) changed how some industries are organized for information collection purposes and thus how certain economic census data are aggregated. Some SIC codes were combined, others were separated, and some activities were classified under one NAICS code and the remaining activities classified under another. The support activities for oil and gas operations is an example of an industry that was reclassified. Under NAICS, SIC 1382, Oil and Gas Exploration Services, and SIC 1389, Oil and Gas Services Not Elsewhere Classified, were combined. The geophysical surveying and mapping services portion of SIC 1382 was reclassified and grouped into NAICS 54136. The adjustments to SIC 1382/89 have made comparison between the 1992 and 1997 economic censes difficult at this time. The U.S. Census Bureau has yet to publish a comparison report. Thus, for NAICS 213112 only 1997 census data are presented. For that year, nearly 6,400 companies operated under NAICS 213112, employing more than 100,000 people and generating $11.5 billion in revenues.

4.1.2 *Supply Side Characteristics*

Characterizing the supply side of the industry involves describing the production processes, the types of output, major by-products, costs of production, and capacity utilization.

4.1.2.1 *Production Processes*

Domestic production occurs within the contiguous 48 states, Alaska, and at offshore facilities. There are four major stages in oil and gas extraction: exploration, well development, production, and site abandonment (EPA, 1999d). Exploration is the search for rock formations associated with oil and/or natural gas deposits. Nearly all oil and natural gas deposits are located in sedimentary rock. Certain geological clues, such as porous rock with an overlying layer of low-permeability rock, help guide exploration companies to a possible source of hydrocarbons. While exploring a potential site, the firm conducts geophysical prospecting and exploratory drilling.

After an economically viable field is located, the well development process begins. Well holes, or well bores, are drilled to a depth of between 1,000 and 30,000 feet, with an average depth of about 5,500 feet (EPA, 1999d). The drilling procedure is the same for both onshore and offshore sites. A steel or diamond drill bit, which may be anywhere between 4 inches and 3 feet in diameter, is used to chip off rock to increase the depth of the hole. The drill bit is connected to the rock by several pieces of hardened pipe known collectively as the drill string. As the hole is drilled, casing is placed in the well to stabilize the hole and prevent caving. Drilling fluid is pumped down through the center of the drill string to lubricate the equipment. The fluid returns to the surface through the space between the drill string and the rock formation or casing. Once the well has been drilled, rigging, derricks, and other production equipment are installed. Onshore fields are equipped with a pad and roads; ships, floating structures, or a fixed platform are procured for offshore fields.

Production is the process of extracting hydrocarbons through the well and separating saleable components from water and silt. Oil and natural gas are naturally occurring co-products, and most production sites produce a combination of oil and gas; however, some wells produce little natural gas, while others may produce only natural gas. Once the hydrocarbons are brought to the surface, they are separated into a spectrum of products. Natural gas is separated from crude oil by passing the hydrocarbons through one or two decreasing pressure chambers. Crude oil is always delivered to a refinery for processing and excess water is removed, at which point the oil is about 98 percent pure, a purity sufficient for storage or transport to a refinery (EPA, 1999b). Natural gas may be processed at the field or at a natural gas processing plant to remove impurities. The primary extracted streams and recovered products associated with the oil and natural gas industry include crude oil, natural gas, condensate, and produced water. The products are briefly described below.

Crude oil can be classified as paraffinic, naphthenic, or intermediate. Paraffinic (or heavy) crude is used as an input to the manufacture of lube oils and kerosene. Naphthenic (or light) crude is used as an input to the manufacture of gasoline and asphalt. Intermediate crudes are those that do not fit into either category. The classification of crude oil is determined by a gravity measure developed by the American Petroleum Institute (API). API gravity is a weight per unit volume measure of a hydrocarbon liquid. A heavy crude is one with an API gravity of 20° or less, and a light crude, which flows freely at atmospheric temperature, usually has an API gravity in the range of the high 30s to the low 40s (EPA, 1999c).

Natural gas is a mixture of hydrocarbons and varying quantities of nonhydrocarbons that exist either in gaseous phase or in solution with crude oil from underground reservoirs. Natural gas may be classified as either wet or dry gas. Wet gas is unprocessed or partially processed natural gas produced from a reservoir that contains condensable hydrocarbons. Dry gas is natural gas whose water content has been reduced through dehydration, or natural gas that contains little or no commercially recoverable liquid hydrocarbons.

Condensates are hydrocarbons that are in a gaseous state under reservoir conditions (prior to production), but which become liquid during the production process. Condensates have an API gravity in the 50° to 120° range (EPA, 1999c). According to historical data, condensates account for about 4.5 to 5 percent of total crude oil production.

Produced water is recovered from a production well or is separated from the extracted hydrocarbon streams. More than 90 percent of produced water is reinjected into the well for disposal and to enhance production by providing increased pressure during extraction. The remainder is released into surface water or disposed of as waste.

In addition to the products discussed above, other various hydrocarbons may be recovered through the processing of the extracted streams. These hydrocarbons include mixed natural gas liquids, natural gasoline, propane, butane, and liquefied petroleum gas.

Natural gas is conditioned using a dehydration and a sweetening process, which removes hydrogen sulfide and carbon dioxide, so that it is of high enough quality to pass through transmission systems. The gas may be conditioned at the field or at one of the 623 operating gas-processing facilities located in gas-producing states, such as Texas, Louisiana, Oklahoma, and Wyoming. These plants also produce the nation's NGLs, propane and butane (NGSA et al., 2000c).

Site abandonment occurs when a site lacks the potential to produce economic quantities of natural gas or when a production well is no longer economically viable. The well(s) are plugged using long cement plugs and steel plated caps, and supporting production equipment is disassembled and moved offsite.

4.1.2.2 *Types of Output*

The oil and gas industry's principal products are crude oil, natural gas, and NGLs (see Tables 4-3 and 4-4). Refineries process crude oil into several petroleum products. These products include motor gasoline (40 percent of crude oil); diesel and home heating oil (20 percent); jet fuels (10 percent); waxes, asphalts, and other nonfuel products (5 percent); feedstocks for the petrochemical industry (3 percent); and other lesser products (EIA, 1999a).

Natural gas is produced from either oil wells (known as "associated gas") or wells that are drilled for the primary objective of obtaining natural gas (known as "nonassociated gas") (see Table 4-4). Methane is the predominant component of natural gas (about 85 percent), but ethane (about 10 percent), propane, and butane are also significant components (see Table 4-3). Propane and butane, the heavier components of natural gas, exist as liquids when cooled and compressed. These latter two components are usually separated and processed as natural gas liquids (EPA, 1999d). A small amount of the natural gas produced is consumed as fuel by the engines used in extracting and transporting the gas, and the remainder is transported through pipelines for use by residential, commercial, industrial, and electric utility users.

Table 4-3. U.S. Supply of Crude Oil and Petroleum Products (10^3 barrels), 1998

Commodity	Field Production	Refinery Production	Imports
Crude Oil	2,281,919		3,177,584
Natural Gas Liquids	642,202	245,918	82,081
Ethane/Ethylene	221,675	11,444	6,230
Propane/Propylene	187,369	200,815	50,146
Normal Butane/Butylene	54,093	29,333	8,612
Isobutane/Isobutylene	66,179	4,326	5,675
Other	112,886		11,418
Other Liquids	69,477		211,266
Finished Petroleum Products	69,427	5,970,090	437,515
Finished Motor Gasoline	69,427	2,880,521	113,606
Finished Aviation Gasoline		7,118	43
Jet Fuel		556,834	45,143
Kerosene		27,848	466
Distillate Fuel Oil		1,249,881	76,618
Residual Fuel Oil		277,957	100,537
Naptha		89,176	22,388
Other Oils		78,858	61,554
Special Napthas		24,263	2,671
Lubricants		67,263	3,327
Waxes		8,355	613
Petroleum Coke		260,061	263
Asphalt and Road Oil		181,910	10,183
Still Gas		239,539	
Miscellaneous Products		20,506	103
Total	3,063,025	6,216,008	3,908,446

Source: Energy Information Administration. 1999b. *Petroleum Supply Annual 1998, Volume I.* Washington, DC: U.S. Department of Energy.

Table 4-4. U.S. Natural Gas Production, 1998

Gross Withdrawals	Production (10^6 cubic feet)
From Gas Wells	17,558,621
From Oil Wells	6,365,612
Less Losses and Repressuring	5,216,477
Total	18,707,756

Source: Energy Information Administration. 1999b. *Natural Gas Annual 1998*. Washington, DC: U.S. Department of Energy.

4.1.2.3 *Major By-Products*

In addition to the various products of the oil and natural gas extraction process described above, there are some additional by-products generated during the extraction process. Oil and natural gas are composed of widely varying constituents and proportions depending on the site of extraction. The removal and separation of individual hydrocarbons during processing is possible because of the differing physical properties of the various components. Each component has a distinctive weight, boiling point, vapor pressure, and other characteristics, making separation relatively simple. Most natural gas is processed to separate hydrocarbon liquids that are more valuable as separate products, such as ethane, propane, butane, isobutane, and natural gasoline. Natural gas may also include water, hydrogen sulfide, carbon dioxide, nitrogen, helium, or other diluents/contaminants. The water present is either recovered from the well or separated from the hydrocarbon streams being extracted. More than 90 percent of the produced water is reinjected into the well to increase pressure during extraction. If hydrogen sulfide, which is poisonous and corrosive, is present, it is removed and further processed to recover elemental sulfur for commercial sale. In addition, processing facilities may remove carbon dioxide to prevent corrosion and to use for injection into the well to increase pressure and enhance oil recovery, recover helium for commercial sale, and may remove nitrogen to increase the heating value of the gas (NGSA et al., 2000c). Finally, the engines that provide pumping action at wells and push crude oil and natural gas through pipes to processing plants, refineries, and storage locations produce HAPs. HAPs produced in engines include formaldehyde, acetaldehyde, acrolein, and methanol.

4.1.2.4 *Costs of Production*

The 42 percent decrease in the number of people employed by the crude oil and natural gas extraction industry between 1992 and 1997 was matched by a corresponding 40 percent decrease in the industry's annual payroll (see Table 4-5). During the same period, industry outlays for supplies, such as equipment and other supplies, increased over 32 percent, and capital expenditures nearly doubled. Automation, mergers, and corporate downsizing have made this industry less labor-intensive (Lillis, 1998).

Unlike the crude oil and gas extraction industry, the NGL extraction industry's payroll increased over 6 percent even though total industry employment declined 12 percent. The industry's expenditures on capital projects, such as investments in fields, production facilities, and other investments, increased 11.4 percent between 1992 and 1997. The cost of supplies did, however, decrease 13 percent from $23.3 billion in 1992 to $20.3 billion in 1997.

Employment increased in NAICS 213111, Drilling Oil and Gas Wells. In 1992, the industry employed 47,700 people, increasing 13 percent to 53,685 in 1997. During a period where industry revenues increased over 100 percent, the industry's payroll increased 41 percent and the cost of supplies increased 182 percent.

4.1.2.5 *Imports and Domestic Capacity Utilization*

Domestic annual oil and gas production is a small percentage of total U.S. reserves. In 1998, oil producers extracted approximately 1.5 percent of the nation's proven crude oil reserves (see Table 4-6). A slightly lesser percentage of natural gas was extracted (1.4 percent), and an even smaller percentage of NGLs was extracted (0.9 percent). The U.S. produces approximately 40 percent (2,281 million barrels) of its annual crude oil consumption, importing the remainder of its crude oil from Canada, Latin America, Africa, and the Middle East (3,178 million barrels). Approximately 17 percent (3,152 billion cubic feet) of U.S. natural gas supply is imported. Most imported natural gas originates in Canadian fields in the Rocky Mountains and off the coast of Nova Scotia and New Brunswick.

Table 4-5. Costs of Production, Crude Oil and Natural Gas Extraction and Related Industries

NAICS	Industry	Employees	Payroll ($1997 10^3)	Cost of Supplies Used, Purchased Machinery Installed, Etc. ($1997 10^3)	Capital Expenditures ($1997 10^3)
211111	Crude Oil and Natural Gas Extraction				
	1992	174,300	$8,331,849	$16,547,510	$10,860,260
	1997	100,308	$4,968,722	$21,908,191	$21,117,850
211112	Natural Gas Liquid Extraction				
	1992	12,000	$509,272	$23,382,770	$609,302
	1997	10,549	$541,593	$20,359,528	$678,479
213111	Drilling Oil and Gas Wells				
	1992	47,700	$1,358,784	$1,344,509	$286,509
	1997	53,865	$1,918,086	$7,317,963	$2,209,300
213112	Support Activities for Oil and Gas Operations				
	1997	106,339	$3,628,416	$3,076,039	$1,165,018

Sources: U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Economic Census, Mining, Industry Series*. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Mineral Industries, Industry Series*. Washington, DC: U.S. Department of Commerce.

Table 4-6. Estimated U.S. Oil and Gas Reserves, Annual Production, and Imports, 1998

Category	Reserves	Annual Production	Imports
Crude Oil (10^6 barrels)	152,453	2,281	3,178
Natural Gas (10^9 cubic feet)	1,330,930	18,708	3,152
Natural Gas Liquids (10^6 barrels)	26,792	246	NA

Sources: Energy Information Administration. 1999d. *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 1998 Annual Report*. Washington, DC: U.S. Department of Energy.

Energy Information Administration. 1999b. *Petroleum Supply Annual 1998, Volume I.* Washington DC: U.S. Department of Energy.

4.1.3 *Demand Side Characteristics*

Characterizing the demand side of the industry involves describing product characteristics. Crude oil, or unrefined petroleum, is a complex mixture of hydrocarbons that is the most important of the primary fossil fuels. Refined petroleum products are used for petrochemicals, lubrication, heating, and fuel. Petrochemicals derived from crude oil are the source of chemical products such as solvents, paints, plastics, synthetic rubber and fibers, soaps and cleansing agents, waxes, jellies, and fertilizers. Petroleum products also fuel the engines of automobiles, airplanes, ships, tractors, trucks, and rockets. Other applications include fuel for electric power generation, lubricants for machines, heating, and asphalt (Berger and Anderson, 1978). Because the market for crude oil is global and its price influenced by OPEC, slight increases in the cost of producing crude oil in the U.S. will have little effect on the prices of products that use crude oil as an intermediate good. Production cost increases are likely to be absorbed mainly by the producer, with little of the increased cost passed along to consumers.

Natural gas is a colorless, flammable gaseous hydrocarbon consisting for the most part of methane and ethane. Natural gas is used by residential, commercial, industrial, and electric utility users. Total consumption of natural gas in the U.S. was 21,262 billion cubic feet in 1998. Industrial consumers accounted for the largest share of this total, consuming 8,686 billion cubic feet, while residential, commercial, and electric utility consumption was 4,520 billion cubic feet, 3,005 billion cubic feet, and 3,258 billion cubic feet, respectively. The remainder of U.S.

consumption was by natural gas producers in their plants and on their gas pipelines. The largest single application for natural gas is as a domestic or industrial fuel. Natural gas is also becoming increasingly important for generating electricity. Although these are the primary uses, other specialized applications have emerged over the years, such as a nonpolluting fuel for buses and other motor vehicles. Carbon black, a pigment made by burning natural gas with little air and collecting the resulting soot, is an important ingredient in dyes, inks, and rubber compounding operations. Also, much of the world's ammonia is manufactured from natural gas; ammonia is used either directly or indirectly in urea, hydrogen cyanide, nitric acid, and fertilizers (Tussing and Tippee, 1995).

The primary substitutes for oil and natural gas are coal, electricity, and each other. Consumers of these energy products are expected to respond to changes in the relative prices between these four energy markets by changing the proportions of these fuels they consume. For example, if the price of natural gas were to increase relative to other fuels, then it is likely that consumers would substitute oil, coal, and electricity for natural gas. This effect of changing prices is commonly referred to as fuel-switching. The extent to which consumers change their fuel usage depends on such factors as the availability of alternative fuels and the capital requirements involved. If they own equipment that can run on multiple fuels, then it may be relatively easy to switch fuel usage as prices change. However, if existing capital cannot easily be modified to run on an alternative fuel, then it is less likely for a consumer to change fuels in the short run. If the relative price of the fuel currently in use remains elevated in the long run, some additional consumers will switch fuels as they replace existing capital with new capital capable of using relatively cheaper fuels. For example, if the price of natural gas were to increase greatly relative to the price of electricity for residential consumers, most consumers are unlikely to replace their natural gas furnaces immediately due to the high cost of doing so. However, new construction would be less likely to include natural gas furnaces, and if the price of natural gas were to remain relatively high compared with electricity in the long run, residential consumers would be more likely to replace their natural gas furnaces with electric heat pumps as their existing furnaces wear out.

4.1.4 *Organization of the Industry*

Many oil and gas firms are merging to remain competitive in both the global and domestic marketplaces. By merging with their peers, these companies may reduce operating expenses and reap greater economies of scale than they would otherwise. Recent mergers, such as BP Amoco and Exxon Mobil, have reduced the number of companies and facilities operating in the U.S. Currently, there are 20 domestic major oil and gas companies, and only 40 major global companies in the world (Conces, 2000). Most U.S. oil and gas firms are concentrated in states with significant oil and gas reserves, such as Texas, Louisiana, California, Oklahoma, and Alaska.

Tables 4-7 through 4-10 present the number of facilities and value of shipments by facility employee count for each of the four industries. In 1997, 6,802 oil and gas extraction companies operated 7,781 facilities, an average of 1.14 facilities per company (see Table 4-7). Facilities with more than 100 employees produced more than 55 percent of the industry's value of shipments. Although the number of companies and the number of facilities operating in 1992 were both greater then than in 1997, the distribution of shipment values by employee size was similar to that of 1992.

Facilities employing fewer than 50 people in the NGLs extraction industry accounted for 64 percent, or $15.8 billion, of the industry's total value of shipments in 1997 (see Table 4-8). 487 of the industry's 529 facilities are in that employment category. This also means that a relatively small number of larger facilities produce 36 percent of the industry's annual output, in terms of dollar value. The number of facilities with zero to four employees and the number with 50 or more employees decreased during the 5-year period, accounting for most of the 10.5 percent decline in the number of facilities from 1992 to 1997. The average number of facilities per company was 5.5 and 5.9 in 1992 and 1997, respectively.

Table 4-7. Size of Establishments and Value of Shipments, Crude Oil and Natural Gas Extraction Industry (NAICS 211111), 1997 and 1992

	1997		1992	
Average Number of Employees in Facility	**Number of Facilities**	**Value of Shipments ($1997 10^3)**	**Number of Facilities**	**Value of Shipments ($1997 10^3)**
0 to 4 employees	5,249	$5,810,925	6184	$5,378,330
5 to 9 employees	1,161	$3,924,929	1402	$3,592,560
10 to 19 employees	661	$4,843,634	790	$4,504,830
20 to 49 employees	412	$10,538,529	523	$8,820,100
50 to 99 employees	132	$8,646,336	203	$5,942,130
100 to 249 employees	105		154	$11,289,730
250 to 499 employees	40		68	$8,135,850
500 to 999 employees	14	$41,318,227	46	$14,693,630
1,000 to 2,499 employees	5		18	$9,265,530
2,500 or more employees	2		3	D
Total	7,781	$75,162,580	9,391	$71,622,600

D = undisclosed.
Sums do not add to totals due to independent rounding.

Sources: U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Economic Census, Mining, Industry Series: Crude Petroleum and Natural Gas Extraction.* EC97N-2111A. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census,of Mineral Industries, Industry Series: Crude Petroleum and Natural Gas*. MIC92-I-13A. Washington, DC: U.S. Department of Commerce.

Table 4-8. Size of Establishments and Value of Shipments, Natural Gas Liquid Extraction Industry (NAICS 211112), 1997 and 1992

	1997		1992	
Average Number of Employees in Facility	**Number of Facilities**	**Value of Shipments ($1997 10^3)**	**Number of Facilities**	**Value of Shipments ($1997 10^3)**
0 to 4 employees	143	$1,407,192	190	$2,668,000
5 to 9 employees	101	$1,611,156	92	$1,786,862
10 to 19 employees	122	$4,982,941	112	$5,240,927
20 to 49 employees	121	$7,828,439	145	$10,287,200
50 to 99 employees	35	$5,430,448	36	$4,789,849
100 to 249 employees	3	D	14	$2,205,819
250 to 499 employees	3	D	2	D
500 to 999 employees	1	D	0	—
1,000 to 2,499 employees	0	—	0	—
2,500 or more employees	0	—	0	—
Total	529	$24,828,503	591	$26,979,200

D = undisclosed.
Sums do not add to totals due to independent rounding.

Sources: U.S. Department of Commerce, Bureau of the Census. 1999b. *1997 Economic Census, Mining, Industry Series: Natural Gas Liquid Extraction*. EC97N-2111b. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995b. *1992 Census of Mineral Industries, Industry Series: Natural Gas Liquids*. MIC92-I-13B. Washington, DC: U.S. Department of Commerce.

As mentioned earlier, the oil and gas well drilling industry's 1997 value of shipments were 106 percent larger than 1992's value of shipments. However, the number of companies primarily involved in this industry declined by 327 over 5 years, and 487 facilities closed during the same period (see Table 4-9). The distribution of the number of facilities by employment size shifted towards those that employed 20 or more people. In 1997, those facilities earned two-thirds of the industry's revenues.

Table 4-9. Size of Establishments and Value of Shipments, Drilling Oil and Gas Wells Industry (NAICS 213111), 1997 and 1992

Average Number of Employees in Facility	1997 Number of Facilities	1997 Value of Shipments ($1997 10^3)	1992 Number of Facilities	1992 Value of Shipments ($1997 10^3)
0 to 4 employees	825	$107,828	1,110	$254,586
5 to 9 employees	215	$231,522	321	$182,711
10 to 19 employees	197	$254,782	244	$256,767
20 to 49 employees	200	$1,008,375	233	$572,819
50 to 99 employees	95	$785,804	120	$605,931
100 to 249 employees	75	$1,069,895	70	$816,004
250 to 499 employees	10	$435,178	19	$528,108
500 to 999 employees	14	$1,574,139	5	$97,254
1,000 to 2,499 employees	6	D	3	$238,427
2,500 or more employees	1	D	—	—
Total	1,638	$7,317,963	2,125	$3,552,707

D = undisclosed.
Sums do not add to totals due to independent rounding.

Sources: U.S. Department of Commerce, Bureau of the Census. 1999c. *1997 Economic Census, Mining, Industry Series: Drilling Oil and Gas Wells*. EC97N-2131A. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995c. *1992 Census of Mineral Industries, Industry Series: Oil and Gas Field Services*. MIC92-I-13C. Washington, DC: U.S. Department of Commerce.

In 1997, 6,385 companies operated 7,068 oil and gas support activities facilities, an average of 1.1 facilities per company. The Inventory Database includes 1,599 facilities in NAICS 21. Most facilities employed four or fewer employees; however, those facilities with 20 or more employees accounted for the majority of the industry's revenues (see Table 4-10).

Table 4-10. Size of Establishments and Value of Shipments, Support Activities for Oil and Gas Operations (NAICS 213112), 1997

Average Number of Employees at Facility	1997	
	Number of Facilities	Value of Shipments ($1997 10^3)
0 to 4 employees	4,122	$706,396
5 to 9 employees	1,143	$571,745
10 to 19 employees	835	$904,356
20 to 49 employees	629	$1,460,920
50 to 99 employees	211	$1,480,904
100 to 249 employees	84	$1,175,766
250 to 499 employees	21	$754,377
500 to 999 employees	13	$1,755,689
1,000 to 2,499 employees	9	D
2,500 or more employees	1	D
Total	7,068	$11,547,563

D = undisclosed.
Sums do not add to totals due to independent rounding.

Source: U.S. Department of Commerce, Bureau of the Census. 1999d. *1997 Economic Census, Mining, Industry Series: Support Activities for Oil and Gas Operations*. EC97N-2131B. Washington, DC: U.S. Department of Commerce.

4.1.5 *Markets and Trends*

Between 1990 and 1998, crude oil consumption increased 1.4 percent per year, and natural gas consumption increased 2.0 percent per year. The increase in natural gas consumption came mostly at the expense of coal consumption (EPA, 1999d). The Energy Information Administration (EIA) anticipates that natural gas consumption will continue to grow at a similar rate through the year 2020 to 32 trillion cubic feet/year. Prices are expected to grow steadily, increasing overall by about 0.6 percent annually (EIA, 1999a). They also expect crude oil consumption to grow at an annual rate of less than 1 percent over the same period (EIA, 1999a). For ease of comparison, the quantities used for all energy markets modeled for this analysis are defined in terms of quadrillions of Btus and prices are defined as dollars per million Btus. In

2005, the year used for this analysis, the EIA (2000c) projects 24.57 quadrillion Btus of natural gas will be consumed at an average price of $4.23/million Btus, and 41.21 quadrillion Btus of petroleum products will be consumed at an average price of $8.22/million Btus.

4.2 NATURAL GAS PIPELINE INDUSTRY

The natural gas pipeline industry (NAICS 4862) comprises establishments primarily engaged in the pipeline transportation of natural gas from processing plants to local distribution systems. Also included in this industry are natural gas storage facilities, such as depleted gas fields and aquifers.

4.2.1 *Introduction*

The natural gas industry can be divided into three segments, or links: production, transmission, and distribution. Natural gas pipeline companies are the second link, performing the vital function of linking gas producers with the local distribution companies and their customers. Pipelines transmit natural gas from gas fields or processing plants through high compression steel pipe to their customers. By the end of 1998, there were more than 300,000 miles of transmission lines (OPS, 2000).

The interstate pipeline companies that linked the producing and consuming markets functioned mainly as resellers or merchants of gas until about the 1980s. Rather than acting as common carriers (i.e., providers only of transportation), pipelines typically bought and resold the gas to a distribution company or to some other downstream pipelines that would later resell the gas to distributers. Today, virtually all pipelines are common carriers, transporting gas owned by other firms instead of wholesaling or reselling natural gas (Tussing and Tippee, 1995).

According to the U.S. Bureau of the Census, the natural gas pipeline industry’s revenues totaled $19.6 billion in 1997. Pipeline companies operated 1,450 facilities and employed 35,789 people (see Table 4-11). The Inventory Database contains 1,401 facilities in NAICS 4862, so the majority of pipeline companies are included. The industry’s annual payroll is nearly $1.9 billion.

Table 4-11. Summary Statistics for the Natural Gas Pipeline Industry (NAICS 4862), 1997

Establishments	1,450
Revenue ($\$10^3$)	$19,626,833
Annual Payroll ($\$10^3$)	$1,870,950
Paid Employees	35,789

Source: U.S. Department of Commerce, Bureau of the Census. 2000. *1997 Economic Census, Transportation and Warehousing: Geographic Area Series*. EC97T48A-US. Washington, DC: Government Printing Office.

The recent transition from the SIC system to the NAICS changed how some industries are organized for information collection purposes and thus how certain economic census data are aggregated. Some SIC codes were combined, others were separated, and some activities were classified under one NAICS code and the remaining activities classified under another. The natural gas transmission (pipelines) industry is an example of an industry code that was reclassified. Under NAICS, SIC 4922, natural gas transmission (pipelines), and a portion of SIC 4923, natural gas distribution, were combined. The adjustments have made comparison between the 1992 and 1997 economic censes difficult at this time. The U.S. Census Bureau has yet to publish a comparison report. Thus, for this industry only 1997 census data are presented.

4.2.2 *Supply Side Characteristics*

Characterizing the supply side involves describing services provided by the industry, by-products, the costs of production, and capacity utilization.

4.2.2.1 *Service Description*

Natural gas is delivered from gas processing plants and fields to distributers via a nationwide network of over 300,000 miles of transmission pipelines (NGSA et al., 2000a). The majority of pipelines are composed of steel pipes that measure from 20 to 42 inches in diameter and operate 24 hours a day. Natural gas enters pipelines at gas fields, storage facilities, or gas processing plants and is "pushed" through the pipe to the city gate or interconnections, the point at which distribution companies receive the gas. Pipeline operators use sophisticated computer and mechanical equipment to monitor the safety and efficiency of the network.

Reciprocating internal combustion engines compress and provide the pushing force needed to maintain the flow of gas through the pipeline. When natural gas is transmitted, it is compressed to reduce the volume of gas and to maintain pushing pressure. The gas pressure in pipelines is usually between 300 and 1,300 psi, but lesser and higher pressures may be used. To maintain compression and keep the gas moving, compressor stations are located every 50 to 100 miles along the pipeline. Most compressors are large reciprocating engines powered by a small portion of the natural gas being transmitted through the pipeline.

There are over 8,000 gas compressing stations along U.S. gas pipelines, each equipped with one or more engines. The combined output capability of U.S. compressor engines is over 20 million horsepower (NGSA et al., 2000a). Nearly 5,000 engines have individual output capabilities from 500 to over 8,000 horsepower. The replacement cost of this subset of larger engines is estimated by the Gas Research Institute to be $18 billion (Whelan, 1998).

Before or after natural gas is delivered to a distribution company, it may be stored in an underground facility. Underground storage facilities are most often depleted oil and/or gas fields, aquifers, or salt caverns. Natural gas storage allows distribution and pipeline companies to serve their customers more reliably by withdrawing more gas from storage during peak-use periods and reduces the time needed to respond to increased gas demand (NGSA et al., 2000b). In this way, storage guarantees continuous service, even when production or pipeline transportation services are interrupted.

4.2.2.2 *Major By-Products*

There are no major by-products of the natural gas pipeline industry itself. However, the engines that provide pumping action at plants and push crude oil and natural gas through pipelines to customers and storage facilities produce HAPs. As noted previously, HAPs produced in engines include formaldehyde, acetaldehyde, acrolein, and methanol.

4.2.2.3 *Costs of Production*

Between 1996 and 2000, pipeline firms committed over $14 billion to 177 expansion and new construction projects. These projects added over 15,000 miles and 36,178 million cubic feet per day (MMcf/d) capacity to the transmission pipeline system. Because there are compression stations about every 50 to 100 miles along gas pipelines, the addition of 15,000 miles of pipeline implies that 150 to 300 compression stations were added. There are varying numbers of engines at different stations, but the average is three engines per compression station in the Inventory Database. Thus, approximately 450 to 900 new engines were added along pipelines over the period 1996 through 2000. Table 4-12 summarizes the investments made in pipeline projects during the past 5 years. Building new pipelines is more expensive than expanding existing pipelines. For the period covered in the table, the average cost per project mile was $862,000. However, the costs for pipeline expansions averaged $542,000, or 29 cents per cubic foot of capacity added. New pipelines averaged $1,157,000 per mile at 48 cents per cubic foot of capacity.

Pipelines must pay for the natural gas that is consumed to power the compressor engines. The amount consumed and the price paid have fluctuated in recent years. In 1998, pipelines consumed 635,477 MMcf of gas, paying, on average, $2.01 per 1,000 cubic feet. Thus, firms spent approximately $1.28 billion in 1998 for the fueling of RICE units used on pipelines. Pipelines used less natural gas in 1998 than in previous years; the price paid for that gas fluctuated between $1.49 and $2.29 between 1994 and 1997 (see Table 4-13). For companies that transmit natural gas through their own pipelines the cost of the natural gas consumed is considered a business expense.

Table 4-12. Summary Profile of Completed and Proposed Natural Gas Pipeline Projects, 1996 to 2000

	All Type Projects						New Pipelines		Expansions	
Year	Number of Projects	System Mileage	New Capacity (Mmcf/d)	Project Costs ($$10^6$)	Average Cost per Mile ($$10^3$)	Costs per Cubic Foot Capacity (cents)	Average Cost per Mile ($$10^3$)	Costs per Cubic Foot Capacity (cents)	Average Cost per Mile ($$10^3$)	Costs per Cubic Foot Capacity (cents)
1996	26	1,029	2,574	$552	$448	21	$983	17	$288	27
1997	42	3,124	6,542	$1,397	$415	21	$554	22	$360	21
1998	54	3,388	11,060	$2,861	$1,257	30	$1,301	31	$622	22
1999	36	3,753	8,205	$3,135	$727	37	$805	46	$527	31
2000	19	4,364	7,795	$6,339	$1,450	81	$1,455	91	$940	57
Total	177	15,660	36,178	$14,285	$862	39	$1,157	48	$542	29

Note: Sums may not add to totals because of independent rounding.

Source: Energy Information Administration. 1999a. *Natural Gas 1998: Issues and Trends*. Washington, DC: U.S. Department of Energy.

Table 4-13. Energy Usage and Cost of Fuel, 1994–1998

Year	Pipeline Fuel (MMcf)	Average Price ($ per 1,000 cubic feet)
1994	685,362	1.70
1995	700,335	1.49
1996	711,446	2.27
1997	751,470	2.29
1998	635,477	2.01

Source: Energy Information Administration. 1999b. *Natural Gas Annual 1998*. Washington, DC: US Department of Energy.

4.2.2.4 *Capacity Utilization*

During the past 15 years, interstate pipeline capacity has increased significantly. In 1990, the transmission pipeline system's capacity was 74,158 Mmcf/day (see Table 4-14). By the end of 1997, capacity reached 85,847 Mmcf/day, an increase of approximately 16 percent. The system's usage, however, has increased at a faster rate than capacity. The average daily flow was 60,286 Mmcf/day in 1997, a 22 percent increase over 1990's rates. Currently, the system operates at approximately 72 percent of capacity.

4.2.2.5 *Imports*

Approximately 17 percent of the U.S. natural gas supply is imported, primarily from Canadian fields. In many economic analyses, the imported supply is treated separately from the domestic supply because of the difference in the impact of domestic regulation. However, it is assumed that the imported gas will still be subject to control costs when it is transported through pipelines in the U.S. Thus, the imported supply is not differentiated because the regulation will affect it in a similar manner to domestically supplied gas since they use the same distribution method.

Table 4-14. Transmission Pipeline Capacity, Average Daily Flows, and Usage Rates, 1990 and 1997

	1990	1997	Percent Change
Capacity (Mmcf per day)	74,158	85,847	16
Average Flow (Mmcf per day)	49,584	60,286	22
Usage Rate (percent)	68	72	4

Source: Energy Information Administration. 1999a. *Natural Gas 1998: Issues and Trends*. Washington, DC: US Department of Energy.

4.2.3 *Demand Side Characteristics*

Most pipeline customers are local distribution companies that deliver natural gas from pipelines to local customers. Many large gas users will buy from marketers and enter into special delivery contracts with pipelines. However, local distribution companies (LDCs) serve most residential, commercial, and light industrial customers. LDCs also use compressor engines to pump natural gas to and from storage facilities and through the gas lines in their service area.

While economic considerations strongly favor pipeline transportation of natural gas, liquified natural gas (LNG) emerged during the 1970s as a transportation option for markets inaccessible to pipelines or where pipelines are not economically feasible. Thus, LNG is a substitute for natural gas transmission via pipelines. LNG is natural gas that has been liquified by lowering its temperature. LNG takes up about 1/600 of the space gaseous natural gas takes up, making transportation by ship possible. However, virtually all of the natural gas consumed in the U.S. reaches its consumer market via pipelines because of the relatively high expense of transporting LNG and its volatility. Most markets that receive LNG are located far from pipelines or production facilities, such as Japan (the world's largest LNG importer), Spain, France, and Korea (Tussing and Tippee, 1995).

4.2.4 *Organization of the Industry*

Much like other energy-related industries, the natural gas pipeline industry is dominated by large investor-owned corporations. Smaller companies are few because of the real estate, capital, and operating costs associated with constructing and maintaining pipelines (Tussing and Tippee, 1995). Many of the large corporations are merging to remain competitive as the industry adjusts to restructuring and increased levels of competition. Increasingly, new pipelines are built by partnerships: groups of energy-related companies share capital costs through joint ventures and strategic alliances (EIA, 1999a). Ranked by system mileage, the largest pipeline companies in the U.S. are El Paso Energy (which recently merged with Southern Natural Gas Co.), Enron, Williams Cos., Coastal Corp., and Duke Energy (see Table 4-15). El Paso Energy and Coastal intend to merge in mid-2000.

4.2.5 *Markets and Trends*

During the past decade, interstate pipeline capacity has increased 16 percent. Many existing pipelines underwent expansion projects, and 15 new interstate pipelines were constructed. In 1999 and 2000, proposals for pipeline expansions and additions called for a $9.5 billion investment, an increase of 16.0 billion cubic feet per day of capacity (EIA, 1999a).

The EIA (1999a), a unit of the Department of Energy, expects natural gas consumption to grow steadily, with demand forecasted to reach 32 trillion cubic feet by 2020. The expected increase in natural gas demand has significant implications for the natural gas pipeline system.

The EIA (1999a) expects the interregional pipeline system, a network that connects the lower 48 states and the Canadian provinces, to grow at an annual rate of 0.7 percent between 2001 and 2020. However, natural gas consumption is expected to grow at more than twice that annual rate, 1.8 percent, over that same period. The majority of the growth in consumption is expected to be fueled by the electric generation sector. According to the EIA, a key issue is what kinds of infrastructure changes will be required to meet this demand and what the financial and environmental costs will be of expanding the pipeline network.

Table 4-15. Five Largest Natural Gas Pipeline Companies by System Mileage, 2000

Company	Headquarters	Sales ($1999 10^6)	Employment (1999)	Miles of Pipeline
El Paso Energy Corporation Incl. El Paso Natural Gas Co. Southern Natural Gas Co. Tennessee Gas Pipe Line Co.	Houston, TX	$5,782	4,700	40,200
Enron Corporation Incl. Northern Border Pipe Line Co. Northern Natural Gas Co. Transwestern Pipeline Co.	Houston, TX	$40,112	17,800	32,000
Williams Companies, Inc. Incl. Transcontinental Gas Pipe Line Northwest Pipe Line Co. Texas Gas Pipe Line Co.	Tulsa, OK	$8,593	21,011	27,000
The Coastal Corporation Incl. ANR Pipeline Co. Colorado Interstate Gas Co.	Houston, TX	$8,197	13,000	18,000
Duke Energy Corporation Incl. Panhandle Eastern Pipeline Co. Algonquin Gas Transmission Co. Texas Eastern Transmission Co.	Charlotte, NC	$21,742	21,000	11,500

Sources: Heil, Scott F., Ed. 1998. *Ward's Business Directory of U.S. Private and Public Companies 1998, Volume 5*. Detroit, MI: Gale Research Inc.

Sales, employment, and system mileage: Hoover's Incorporated. 2000. Hoover's Company Profiles. Austin, TX: Hoover's Incorporated. <http://www.hoovers.com/>.

5.0 ECONOMIC IMPACT ANALYSIS

The proposed rule to control emissions of HAPs from RICE will affect many U.S. industries because these engines are primarily used as inputs in extracting and transporting fuels (oil and natural gas). Therefore, the proposed regulations will increase the cost of producing these fuels and will lead to an increase in energy costs to industrial, commercial, and residential customers. In addition to the effect on energy prices, many industrial facilities use RICE as part of their production process and will face direct control costs on these engines. The response of producers to these additional costs determines the economic impacts of the regulation. Specifically, the cost of the regulation may induce some owners to change their current operating rates or even to close their operations (either the entire facility or individual product lines). These choices affect, and in turn are affected by, the market prices for fuels and the market prices in the final product markets. This section describes the methodology, data, and model used to estimate the economic impacts of the proposed regulation for the year 2005 and provides the economic analysis results

5.1 ECONOMIC IMPACT METHODOLOGY

This section summarizes the Agency's approach to modeling the responses of fuel markets to the imposition of the proposed regulation. In conducting an economic analysis and determining the economic impacts, the analyst should recognize the alternatives available to each producer in response to the regulation and the context of these choices. The Agency evaluated the economic impacts of this NESHAP using a market-based approach that gives producers the choice of whether to continue producing these products and, if so, to determine the optimal level consistent with market signals.

The Agency's approach is soundly based on standard microeconomic theory, employs a comparative statics approach, and assumes certainty in relevant markets. Supply curves were developed for each energy market (see Appendix A), and prices and quantities were determined in perfectly competitive markets for each fuel market and each final product and service market.

5.1.1 *Background on Economic Modeling Approaches*

In general, the economic analysis methodology needs to allow EPA to consider the effects of the different regulatory alternatives. Several types of economic impact modeling approaches have been developed to support regulatory development. These approaches can be viewed as varying along two modeling dimensions:

- the scope of economic decision making accounted for in the model and
- the scope of interaction between different segments of the economy.

Each of these dimensions was considered in determining the approach for this study. The advantages and disadvantages of different modeling approaches are discussed below.

5.1.1.1 *Modeling Dimension 1: Scope of Economic Decision making*

Models incorporating different levels of economic decision making can generally be categorized as *with* behavior responses and *without* behavior responses (accounting approach). Table 5-1 provides a brief comparison of the two approaches. The nonbehavioral approach essentially holds fixed all interactions between facility production and market forces. It assumes that firms absorb all control costs and consumers do not face any of the costs of regulation.

Table 5-1. Comparison of Modeling Approaches

EIA With Behavioral Responses
• Incorporates control costs into production function
• Includes change in quantity produced
• Includes change in market price
• Estimates impacts for
T affected producers
T unaffected producers
T consumers
T foreign trade
EIA Without Behavioral Responses
• Assumes firm absorbs all control costs
• Typically uses discounted cash flow analysis to evaluate burden of control costs
• Includes depreciation schedules and corporate tax implications
• Does *not* adjust for changes in market price
• Does *not* adjust for changes in plant production

Typically, engineering control costs are weighted by the number of affected units to develop "engineering" estimates of the total annualized costs. These costs are then compared to company or industry sales to determine the regulation's impact.

In contrast, the behavioral approach is grounded in economic theory related to producer and consumer behavior in response to changes in market conditions. Owners of affected facilities are economic agents that can, and presumably will, make adjustments such as changing production rates or altering input mixes that will generally affect the market environment in which they operate. As producers change their behavior in response to regulation, consumers are typically faced with changes in prices that cause them to alter the quantity that they are willing to purchase. In essence, this approach models the expected reallocation of society's resources in response to a regulation. The changes in price and production from the market-level impacts are used to estimate the distribution of social costs between consumers and producers.

5.1.1.2 *Modeling Dimension 2: Interaction Between Economic Sectors*

Because of the large number of markets potentially affected by the regulation on RICE, an issue arises concerning the level of sectoral interaction to model. In the broadest sense, all markets are directly or indirectly linked in the economy; thus, all commodities and markets are to some extent affected by the regulation. For example, controls on RICE may indirectly affect almost all markets for goods and services to some extent because the cost of fuel (an input in the provision of most goods and services) is likely to increase with the regulation in effect. However, the impact of rising fuel prices will differ greatly between different markets depending on how important fuel is as an input in that market.

The appropriate level of market interactions to be included in the EIA is determined by the scope of the regulation across industries and the ability of affected firms to pass along the regulatory costs in the form of higher prices. Alternative approaches for modeling interactions between economic sectors can generally be divided into three groups:

- Partial equilibrium model: Individual markets are modeled in isolation. The only factor affecting the market is the cost of the regulation on facilities in the industry being modeled.
- General equilibrium model: All sectors of the economy are modeled together. General equilibrium models operationalize neoclassical microeconomic theory by modeling not only the direct effects of control costs, but also potential input substitution effects, changes in production levels associated with changes in market prices across all sectors, and the associated changes in welfare economywide. A disadvantage of general equilibrium modeling is that substantial time and resources are required to develop a new model or tailor an existing model for analyzing regulatory alternatives.
- Multiple-market partial equilibrium model: A subset of related markets are modeled together, with intersectoral linkages explicitly specified. To account for the relationships and links between different markets without employing a full general equilibrium model, analysts can use an integrated partial equilibrium model. The multiple-market partial equilibrium approach represents an

intermediate step between a simple, single-market partial equilibrium approach and a full general equilibrium approach. This approach involves identifying and modeling the most significant subset of market interactions using an integrated partial equilibrium framework. In effect, the modeling technique is to link a series of standard partial equilibrium models by specifying the interactions between supply functions and then solving for prices and quantities across all markets simultaneously. In instances where separate markets are closely related and there are strong interconnections, there are significant advantages to estimating market adjustments in different markets simultaneously using an integrated market modeling approach.

5.1.2 *Selected Modeling Approach for RICE Analysis*

To conduct the analysis for the RICE MACT, the Agency used a market modeling approach that incorporates behavioral responses in a multiple-market partial equilibrium model as described above. This approach allows for a more realistic assessment of the distribution of impacts across different groups than the nonbehavioral approach, which may be especially important in accurately assessing the impacts of a significant rule affecting numerous industries. Because of the size and complexity of this regulation, it is important to use a behavioral model to examine the distribution of costs across society. Because the regulations on RICE affect energy costs, an input into many production processes, complex market interactions need to be captured to provide an accurate picture of the distribution of regulatory costs. Because of the large number of affected industries under this MACT, an appropriate model should include multiple markets and the interactions between them. Multiple-market partial equilibrium analysis provides a manageable approach to incorporate interactions between energy markets and product markets into the economic analysis to accurately estimate the regulation's impact.

The model used for this analysis includes industrial (manufacturing), commercial, residential, transportation, and energy markets affected by the controls placed on engines. The industrial and commercial sectors are divided into 24 final product and service markets.[1] The energy markets are divided into natural gas, petroleum products, coal, and electricity.

Figure 5-1 presents an overview of the key market linkages included in the economic impact model we propose to use for analyzing the RICE MACT. The analysis' emphasis is on the energy supply chain, including the extraction and transportation of natural gas and petroleum, the generation of electricity, and the consumption of energy by producers of final products and services. The industries most directly affected by the RICE MACT are those involved in extracting and transporting natural gas. However, changes in the equilibrium price and quantity of natural gas affect all of the other energy markets. As shown in Figure 5-1, wholesale electricity generators consume natural gas, petroleum products, and coal to generate electricity that is then used to produce final products and services. In addition, many final product markets use natural gas and petroleum products directly as an input into their production process. This analysis explicitly models the linkages between these market segments.

RICE are used to extract and transport natural gas and petroleum products used by a wide range of industrial, commercial, residential, and transportation sectors in the U.S. economy. As a result, control costs associated with the proposed regulation will directly affect the cost of

- extraction and transportation of natural gas and petroleum products using RICE to generate compression and
- using RICE directly as part of a production process, such as for rock crushing in the mining sector.

[1]These markets are defined at the two- and three-digit NAICS code level. This allows for a fairly disaggregated examination of the regulation's impact on producers. However, if the costs of the regulation are concentrated on a particular subset of one of these markets, then treating the cost as if it fell evenly on the entire NAICS code may underestimate the impacts on the subset of producers that are affected by the regulation.

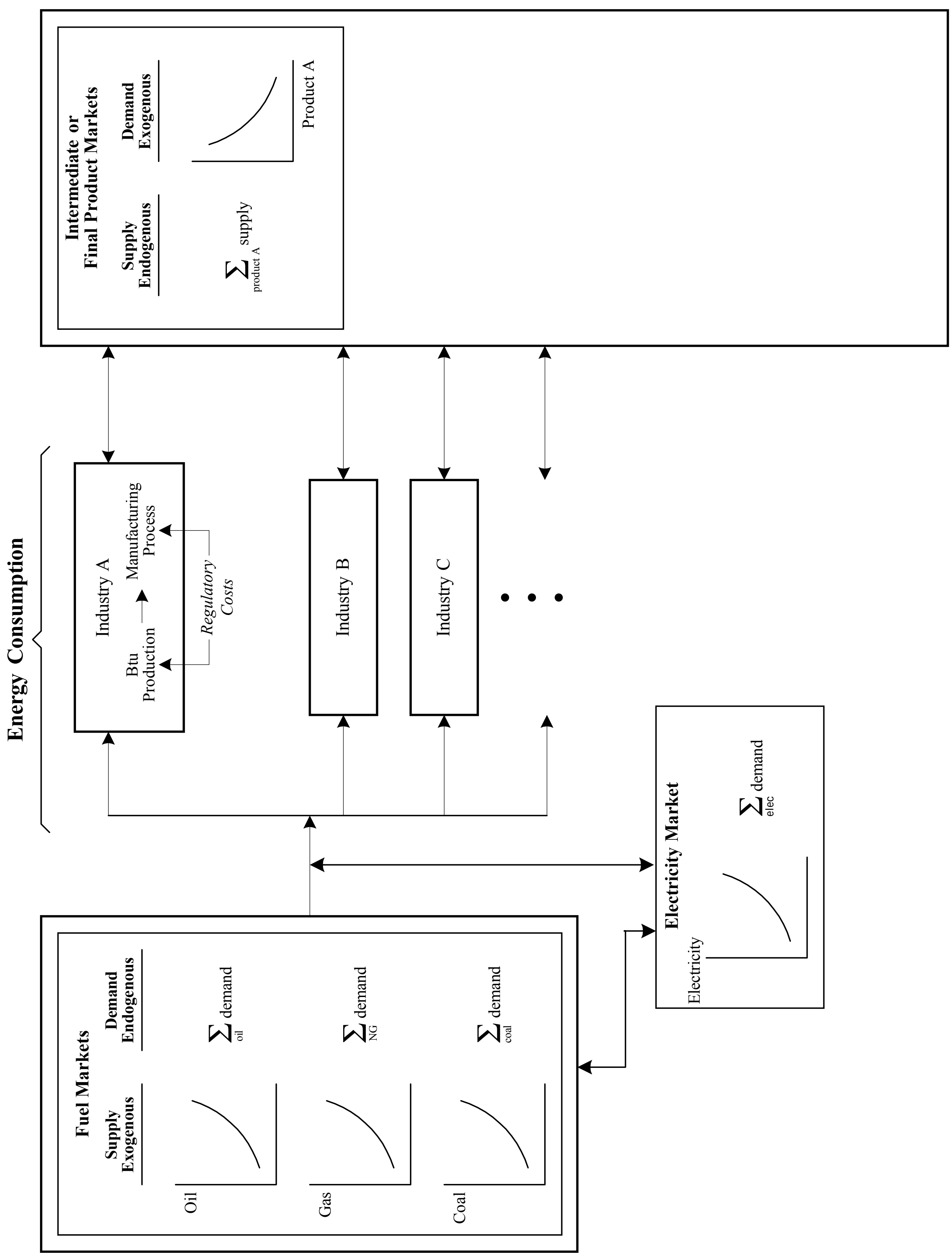

Figure 5-1. Links Between Energy and Final Product Markets

> There are several categories of RICE, as described in Section 2. The categories that fall under the proposed regulation are spark ignition 2SLB, spark ignition 4SLB, spark ignition 4SRB, and CI RICE.[2] Most industries that use engines use multiple categories. 2SLB, 4SLB, and 4SRB engines are all used primarily in either oil and gas extraction or on natural gas pipelines. They are also distributed across many other industrial and commercial SIC codes, although in relatively small numbers. The CI engines in the Inventory Database fall mainly in the hospital services industry and in other commercial businesses.

In addition to the direct impact of control costs on entities installing new RICE and existing entities using 4SRB, indirect impacts are passed along the energy supply chain through changes in prices. For example, production costs will increase for mining companies using RICE as a result of the direct control costs on RICE as well as the resulting increase in the price of natural gas and electricity used as energy inputs in the production process.

Also included in the impact model is feedback of changes in output in the final product markets into the demand for Btus in the fuel markets. The change in facility output is determined by the size of the Btu cost increase (typically variable cost per output), the facility's production function (slope of facility-level supply curve), and the characteristics of the facility's downstream market (other market suppliers and market demanders). For example, if consumers' demand for a final product is not very sensitive to price, then producers can pass the majority of the cost of the regulation through to consumers and the facility output may not change appreciably. However, if only a small proportion of market output is produced at facilities affected by the regulation, then competition will prevent the affected facilities from raising their prices significantly.

One possible feedback pathway that this analysis does *not* plan on modeling is technical changes in the manufacturing process. For example, if the cost of Btus increases, a facility may use measures to increase manufacturing efficiency or capture waste heat. Facilities could also possibly change the input mix that they use, substituting other inputs for fuel. These facility-

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[2]Although CI engines can be either 2SLB or 4SLB, these two categories have been combined for this analysis, and the acronyms 2SLB and 4SLB are reserved for spark ignition engines of these configurations.

level responses will also act to reduce pollution, but including these responses is beyond the scope of this analysis.

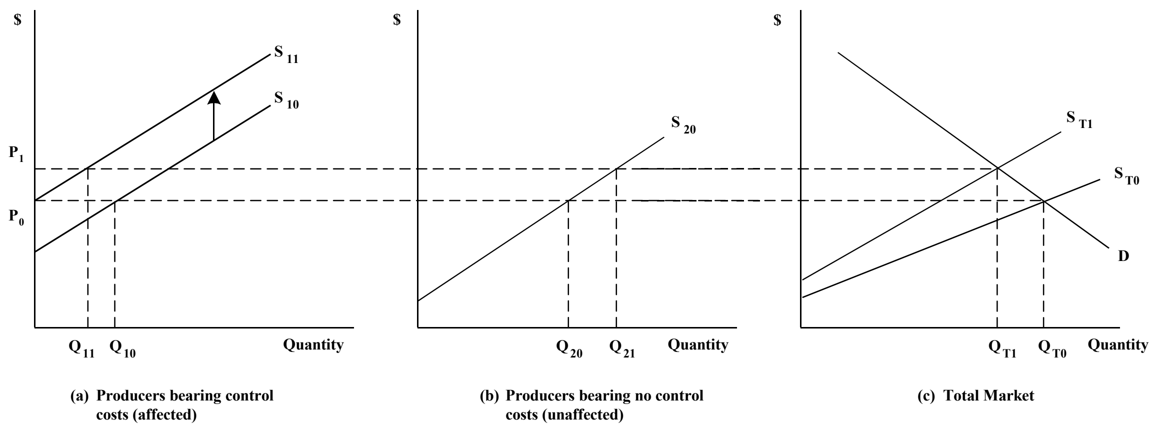
The intermarket linkages connecting the fuel markets and final product markets are described in the sections below.

5.1.3 *Directly Affected Markets*

Markets where RICE are used as an input to production are considered to be directly affected. Producers using engines will be required to add costly controls to any new engines that they acquire and to existing 4SRB engines. They also must incur monitoring costs to ensure that the controls are working properly. Therefore, the regulation will increase their production costs and cause these directly affected firms to reduce the quantity that they are willing to supply at any given price.

5.1.3.1 *Market for Natural Gas*

Because the majority of RICE are used in either extracting oil and natural gas or transporting natural gas, the energy market most directly affected by the proposed regulations is the natural gas industry. Because it will be more costly to produce natural gas under the new regulations, firms involved in producing natural gas are expected to supply less gas to the market at any given price than they did prior to the new rule. These decreases at the facility level will lead to a decrease in industry supply. The magnitude of the upward shift in the supply curve and the price elasticities of supply and demand are the two factors that determine the impacts on the natural gas market. Because 25 percent of 4SRB and 3 percent of 4SLB engines are projected to be controlled in the absence of the proposed regulation, these engines are considered to be unaffected by the regulation. Figure 5-2 illustrates the shifts in the supply curves for a representative energy market.



P_0 = market price without regulation
P_1 = market price with regulation
S_{10} = supply function for affected firms without regulation
S_{11} = supply function for affected firms with regulation
Q_{10} = quantity sold for affected firms without regulation
Q_{11} = quantity sold for affected firms with regulation
S_{20} = supply function for unaffected firms both with and without regulation
Q_{20} = quantity sold for unaffected firms without regulation
Q_{21} = quantity sold for unaffected firms with regulation
S_{T0} = total market supply function without regulation
S_{T1} = total market supply function with regulation
Q_{T0} = total market quantity sold without regulation
Q_{T1} = total market quantity sold with regulation

Figure 5-2. Market Effects of Regulation-Induced Costs

5.1.3.2 *Market for Petroleum Products*

The market for petroleum products is also included in the economic impact model for RICE. For petroleum products, a single composite product is used to model market adjustment. A composite product was used in this market because engines are used in the extraction of crude petroleum; as a result, the increased production costs were not assigned to specific end products, such as fuel oil #2 or reformulated gasoline. This will tend to understate the impacts for petroleum products where extraction costs as a percentage of production costs are greater than average and overstate impacts for products where extraction costs as a percentage of production costs are less than average.

Control costs associated with RICE will increase the cost of petroleum extraction. The cost impacts are assumed to be distributed over all domestically consumed petroleum products. This is because it is assumed that affected units will be distributed across all firms involved in the production of these products. The supply curve for petroleum products will shift upward by the proportional increase in total production costs caused by the control costs on RICE.

5.1.3.3 *Final Product and Service Markets*

Final product and service markets are also directly affected by the regulation. Many manufacturing facilities use engines in their production processes. Commercial entities use engines as generators, especially in the health services field. In addition to the direct costs of the regulation, final product and service markets are indirectly affected through price increases in the energy markets.

Directly affected producers of final products and services are segmented into industrial and commercial sectors defined at the two- and three-digit NAICS code level. A partial equilibrium analysis was conducted to model the supply and demand for final product and service markets. Changes in production levels and fuel switching due to the regulation's impact on the price of Btus were then linked back into the energy markets.

Impact on the Final Product and Service Markets. The impact of the regulation on manufacturers in this sector is modeled as an increase in the cost of Btus used in the production process. In this context, Btus refer to the generic energy requirements that are used to generate process heat, process steam, or shaft power. Compliance costs associated with the regulation will increase the cost of Btu production in the manufacturing sectors. The cost of Btu production for industry increases due to both direct control costs on engines owned by manufacturers and increases in the price of fuels. Because Btus are an input into the production process, these price increases lead to an upward shift in the facility (and industry) supply curves as shown in Figure 5-2, leading to a change in the equilibrium market price and quantity.

The changes in equilibrium supply and demand in each final product and service market are modeled to estimate the regulation's impact on each manufacturing sector. In a perfectly competitive market, the point where supply equals demand determines the market price and quantity, so market price and quantity are determined by solving the model for the price where the quantity supplied and the quantity demanded are equal. The size of the regulation-induced shifts in the supply curve are a function of the total direct control costs associated with new engines and existing 4SRB engines and the indirect fuel costs (determined by the change in fuel price and intensity of use) in each final product and service market. The proportional shift in the supply curve is determined by the ratio of total control costs (both direct and indirect) to production costs.

This impact on the price of Btus facing industrial users feeds back to the fuel market in two ways (see Figure 5-3). The first is through the company's input decision concerning the fuel(s) that will be used for its manufacturing process. As the cost of Btus increases, firms may switch fuels and/or change production processes to increase energy efficiency and reduce the number of Btus required per unit of output. Fuel switching impacts are modeled using cross-price elasticities of demand between energy sources. For example, a cross-price elasticity of demand between natural gas and electricity of 0.5 implies that a 1 percent increase in the price of electricity will lead to a 0.5 percent increase in the demand for natural gas. Own-price elasticities of demand are used to estimate the change in the use of fuel by demanders. For example, a demand elasticity of –0.175 for electricity implies that a 1 percent increase in the price of electricity will lead to a 0.175 percent decrease in the quantity of electricity demanded.

The second feedback pathway to the energy markets is through the facility's change in output. Because Btus are an input into the production process, price increases lead to an upward shift in the facility supply curves (not modeled individually). This leads to an upward shift in the industry supply curve when the shifts at the facility level are aggregated across facilities. A shift in the industry supply curve leads to a change in the equilibrium market price and quantity. In a perfectly competitive market, the point where supply equals demand determines the market price and quantity. The Agency assumes constant returns to scale in production so that the percentage change in Btus consumed by manufacturers equals the percentage change in the equilibrium market quantity in each final product and service market.

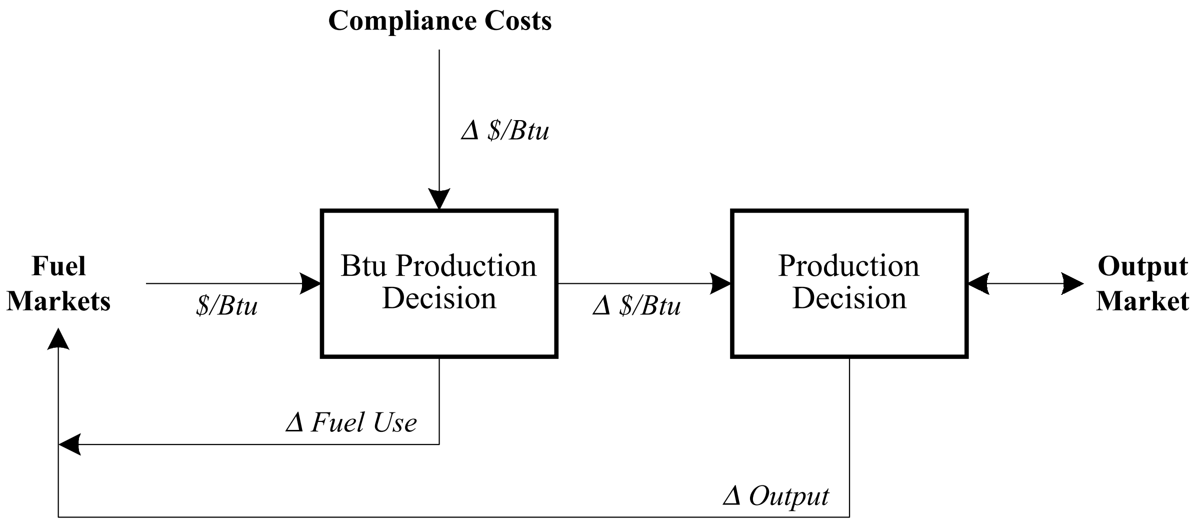


Figure 5-3. Fuel Market Interactions with Facility-Level Production Decisions

The Agency assumed that the demand curves for final products and services in all manufacturing sectors are unchanged by the regulation. However, because the demand function quantifies the change in quantity demanded in response to a change in price, the baseline demand conditions are important in determining the regulation's impact. The key demand parameters will be the elasticities of demand with respect to changes in the price of final products. For these markets, a "reasonable" range of elasticity values is assigned based on estimates from similar commodities. Because price changes are anticipated to be small, the point elasticities at the original price and quantity should be applicable throughout the relevant range of prices and quantities examined in this model.

5.1.4 *Indirectly Affected Markets*

In addition to the many markets that are directly affected by the regulation on RICE, some markets feel the regulation's impacts despite having no direct costs resulting from the regulation. Firms in these markets generally face changes in the price of energy that affect their production decisions.

5.1.4.1 *Market for Electricity*

Although EPA assumed that there are no direct impacts on the production of electricity because engines are not commonly used by utilities to generate power, the market for electricity will still be indirectly affected through changes in fuel prices. Electricity generators are extremely large consumers of coal and natural gas as well as petroleum products to a lesser extent. These fuels are used to generate electricity, so as the prices of fuels rise, there is a decrease in the amount of electricity that producers are willing to supply. This impact feeds back into the fuel markets as utilities reduce their purchases of fuels. In addition to the decrease in supply due to the regulation, an increase in demand is expected as fuel consumers switch from natural gas and petroleum to electricity. Therefore, it is ambiguous whether equilibrium quantity will rise or fall. The price elasticities of supply and demand are the important factors influencing the size of the impacts and whether quantity will increase or decrease.

5.1.4.2 *Market for Coal*

The coal market is not directly affected by the regulation, but it is included in the market model. Although engines are not commonly used in the production or transportation of coal, the supply of coal will be affected by the price of energy used in coal production, and the demand for coal by utility generators and manufacturers will be affected through changes in the relative price of alternative (noncoal) energy sources such as natural gas and petroleum products. The demand for coal from the industrial, transportation and, residential sectors will increase as consumers switch away from the fuels that face increases in price due to controls. The demand for coal from electric utilities may either increase or decrease depending on whether the equilibrium quantity of electricity rises or falls as a result of the regulation.

5.1.4.3 *Final Product and Service Markets*

Some final product markets do not include any engines and are therefore not directly affected by the RICE MACT. However, these markets will still be affected indirectly due to the changes in energy prices that they will face following the regulation. There will be a tendency for these users to shift away from natural gas and petroleum products and towards electricity and coal.

5.1.4.4 *Impact on Residential Sector*

The residential sector does not bear any direct costs associated with the regulation because they do not own RICE. However, they bear indirect costs due to price increases. The residential sector is a significant consumer of electricity, natural gas, and petroleum products used for heating, cooling, and lighting, as well as many other end uses. The change in the quantity of energy demanded by these consumers in response to changes in energy prices is modeled as a single demand curve parameterized by demand elasticities for residential consumers obtained from the literature. Once again, it is expected that in addition to a decrease in the total amount of energy consumed, there will be reallocation across fuels consumed.

5.1.4.5 *Impact on Transportation Sector*

The transportation sector does not face any direct costs due to the regulation because RICE are not typically used in this sector. The main fuels used in this market are petroleum products. The change in the quantity of energy demanded by these consumers in response to changes in prices is modeled as a single demand curve parameterized by demand elasticities for this sector from the literature. The major impact on this market is an increase in the price of a key input causing a reduction in output. There may also be some fuel switching in this sector towards electricity and coal.

5.2 OPERATIONALIZING THE ECONOMIC IMPACT MODEL

Figure 5-4 illustrates the linkages used to operationalize the estimation of economic impacts associated with the compliance costs. Compliance costs placed on existing 4SRB and new RICE shift the supply curve for natural gas and petroleum because RICE are used in the extraction and transportation of these fuels. Adjustments in the natural gas and petroleum energy markets determine the share of the cost increases that producers (natural gas and petroleum companies) and consumers (electricity utilities, product manufacturers, commercial business, and residential households) bear. There are also some relatively small compliance costs on the electricity market from the very few affected engines used in this market.

Increased fuel costs for electricity generators will decrease the supply of electricity. The new equilibrium price and quantity in the electricity market will determine the distribution of impacts between producers (electricity generators) and consumers (product manufacturers, commercial businesses, and residential households). Changes in wholesale electricity generators' demand for input fuels (due to changes in the market quantity of electricity) feed back into the natural gas and petroleum markets as utilities change the allocation of fuels used as inputs.

Manufacturers experience supply curve shifts due to control costs on affected engines they operate and increased prices for natural gas, petroleum, and electricity. The share of these costs borne by producers (manufacturers) and consumers is determined by the new equilibrium price and quantity in the final product markets. Changes in manufacturers' Btu demands due to fuel switching and changes in production levels feed back into the electricity, natural gas, and petroleum markets. Adjustments in price and quantity in all energy and final product markets occur simultaneously. A computer model was used to numerically simulate market adjustments by iterating over commodity prices until equilibrium is reached (i.e., until the quantity supplied equals the quantity demanded in all markets being modeled). Using the results provided by the model, economic impacts of the regulation (changes in consumer and producer surplus) were estimated for all sectors of the economy being modeled.

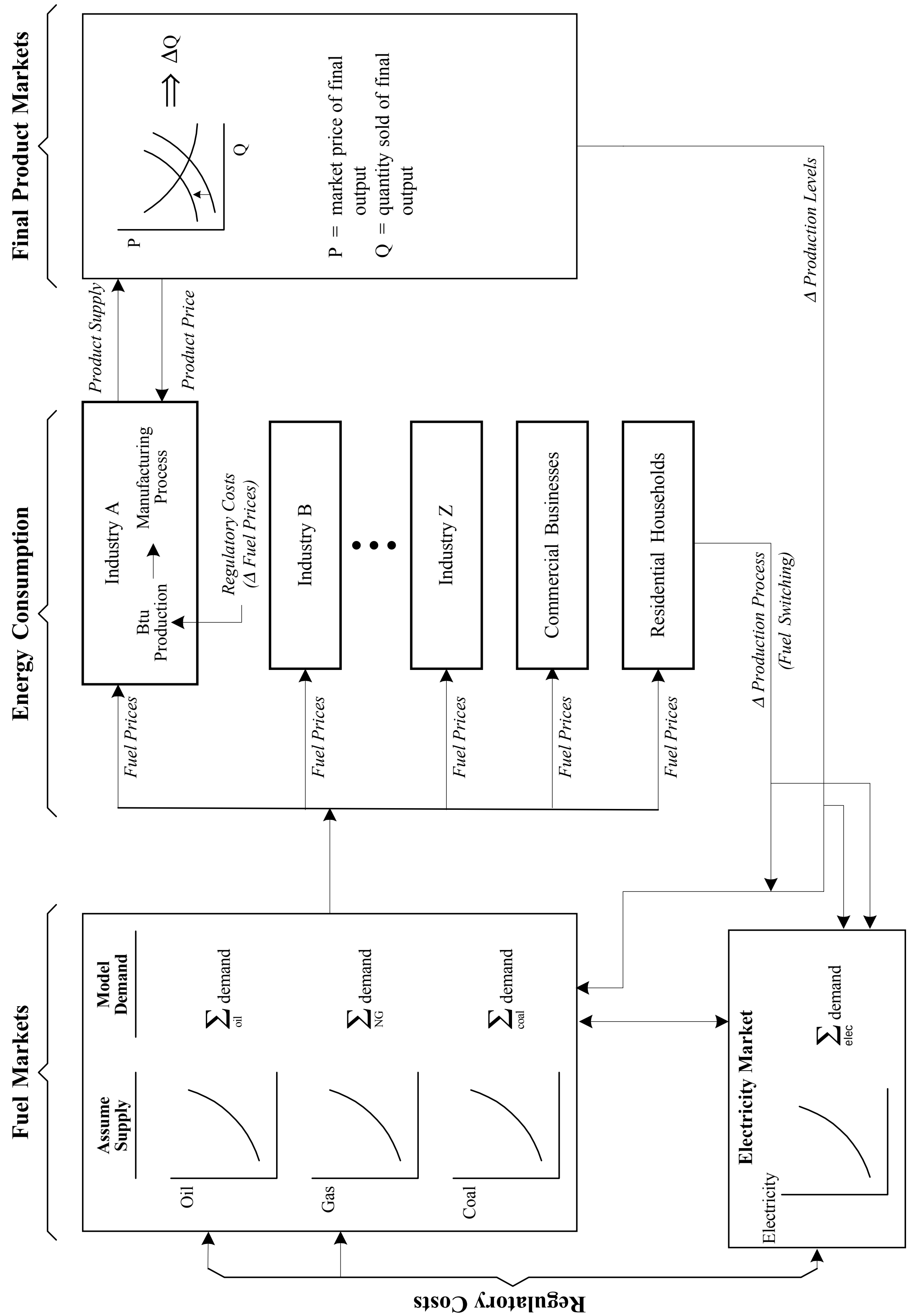


Figure 5-4. Operationalizing the Estimation of Economic Impact

5.2.1 *Computer Model*

The computer model comprises a series of computer spreadsheet modules. The modules integrate the engineering cost inputs and the market-level adjustment parameters to estimate the regulation's impact on the price and quantity in each market being analyzed. At the heart of the model is a market-clearing algorithm that compares the total quantity supplied to the total quantity demanded for each market commodity.

Forecast prices and production levels for 2005 are used to calibrate the baseline scenario (without regulation) for the model. Then, the compliance costs associated with the regulation are introduced as a "shock" to the system, and the supply and demand for market commodities are allowed to adjust to account for the increased production costs resulting from the regulation. Using an iterative process, if the supply does not equal demand in all markets, a new set of prices is "called out" and sent back to producers and consumers to "ask" what quantities they would supply and demand based on these new prices. This technique is referred to as an auctioneer approach because new prices are continually called out until an equilibrium set of prices is determined (i.e., where supply equals demand for all markets).

Supply and demand quantities are computed at each price iteration. The market supply for each energy and final product market is obtained by using a mathematical specification of the supply function, and the key parameter is the point elasticity of supply at the baseline condition.

The demand curves for the energy markets are the sum of demand responses across all markets. For example, the demand for natural gas is the sum of the demand for the electricity industry, all manufacturing sectors, the commercial sector, and the residential sector. The demand for electricity is the sum of the demand for the manufacturing sectors, the commercial sector, and the residential sector. The demand for energy in the manufacturing sectors is a derived demand calculated using baseline energy usage and changes associated with fuel switching and changes in production levels.

The demand for final products in the two- and three-digit NAICS code manufacturing sectors is obtained by using a mathematical specification of the demand function. Similarly, the energy demand in the commercial and residential sectors is obtained through mathematical specification of the demand functions (see Appendix A).

EPA modeled fuel switching using secondary data developed by the U.S. Department of Energy for the National Energy Modeling System (NEMS). Table 5-2 contains fuel price elasticities of demand for electricity, natural gas, petroleum products, and coal. The diagonal elements in the table represent own-price elasticities. For example, the table indicates that for steam coal, a 1 percent change in the price of coal will lead to a 0.499 percent decrease in the use of coal. The off diagonal elements are cross-price elasticities and indicate fuel switching propensities. For example, for steam coal, the second column indicates that a 1 percent increase in the price of coal will lead to a 0.061 percent increase in the use of natural gas.

Table 5-2. Fuel Price Elasticities

	Own and Cross Elasticities in 2015				
Inputs	**Electricity**	**Natural Gas**	**Coal**	**Residual**	**Distillate**
Electricity	–0.074	0.092	0.605	0.080	0.017
Natural Gas	0.496	–0.229	1.087	0.346	0.014
Steam Coal	0.021	0.061	–0.499	0.151	0.023
Residual	0.236	0.036	0.650	–0.587	0.012
Distillate	0.247	0.002	0.578	0.044	–0.055

Source: U.S. Department of Energy, Energy Information Administration (EIA). January 1998. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System*. DOE/EIA-M064(98). Washington, DC: U.S. Department of Energy.

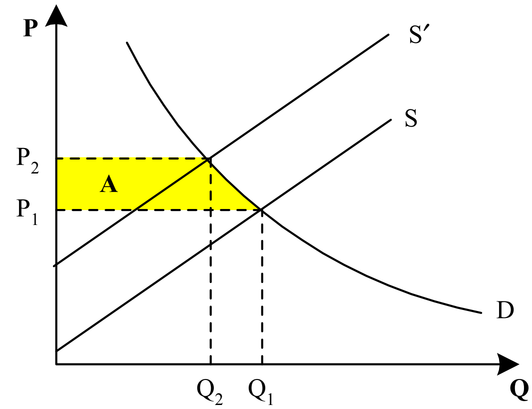
5.2.2 Calculating Changes in Social Welfare

The RICE MACT will impact almost every sector of the economy either directly through control costs or indirectly through changes in the price of energy and final products. For example, a share of control costs that originate in the energy markets is passed through the final product markets and borne by both the producers and consumers of final products. To estimate the total change in social welfare without double-counting impacts across the linked partial equilibrium markets being modeled, EPA quantified social welfare changes for the following categories:

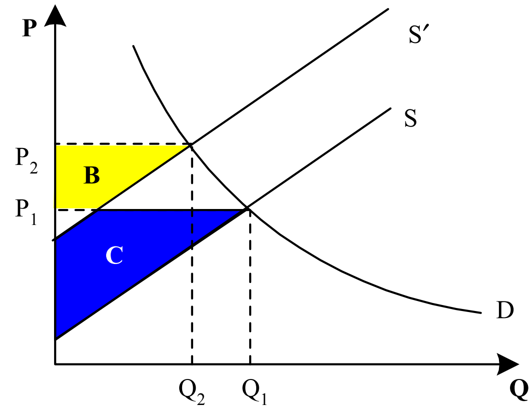
- change in producer surplus in the energy markets,
- change in producer surplus in the final product markets,
- change in consumer surplus in the final product markets, and
- change in consumer surplus in the residential, commercial, and transportation energy markets.

Figure 5-5 illustrates the change in producer and consumer surplus in the intermediate energy market and the final product markets. For example, assume a simple world with only one energy market, wholesale electricity, and one final product market, pulp and paper. If the regulation increased the cost of generating wholesale electricity, then part of the cost of the regulation will be borne by the electricity producers as decreased producer surplus, and part of the costs will be passed on to the pulp and paper manufacturers. In Figure 5-5(a), the pulp and paper manufacturers are the consumers of electricity, so the change in consumer surplus is displayed. This change in consumer surplus in the energy market is captured by the final product market (because the consumer is the pulp and paper industry in this case), where it is split between consumer surplus and producer surplus in those markets. Figure 5-5(b) shows the change in producer surplus in the energy market, where B represents an increase in producer surplus and C represents a decrease.

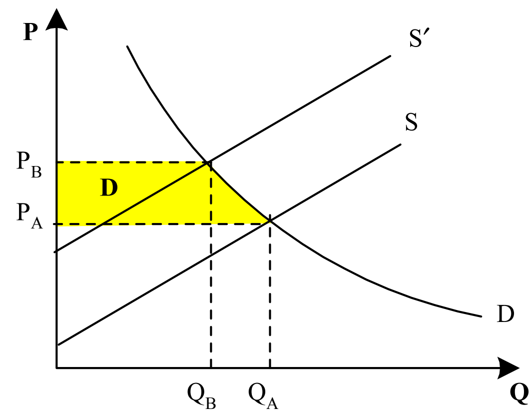
As shown in Figures 5-5(c) and 5-5(d), the cost affects the pulp and paper industry by shifting up the supply curve in the pulp and paper market. These higher electricity prices therefore lead to costs in the pulp and paper industry that are distributed between producers and consumers of paper products in the form of lower producer surplus and lower consumer surplus. Note that the change in consumer surplus in the intermediate energy market must equal the total change in consumer and producer surplus in the final product market. Thus, to avoid double-



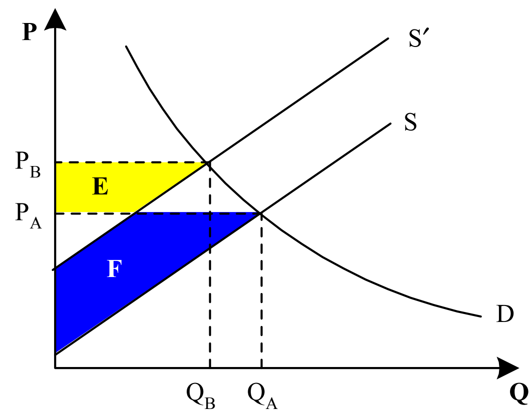
(a) Change in Consumer Surplus in the Energy Market



(b) Change in Producer Surplus in the Energy Market



(c) Change in Consumer Surplus in Final Product Markets



(d) Change in Producer Surplus in Final Product Markets

Figure 5-5. Changes in Economic Welfare with Regulation

counting, the change in consumer surplus in the intermediate energy market was not quantified; instead the total change in social welfare was calculated as

(5.1) $$\text{Change in Social Welfare} = \Sigma\Delta PSE + \Sigma\Delta PSF + \Sigma\Delta CSF + \Sigma\Delta CSR$$

where

ΔPSE = change in producer surplus in the energy markets,

ΔPSF = change in producer surplus in the final product markets,

ΔCSF = change in consumer surplus in the final product markets, and

ΔCSR = change in consumer surplus in the commercial, residential, and transportation energy markets.

Appendix A contains the mathematical algorithms used to calculate the change in producer and consumer surplus in the appropriate intermediate and final product markets.

The engineering control costs presented in Section 2.3 are inputs (regulatory "shocks") in the market model approach. The magnitude and distribution of the regulatory costs' impact on the economy depend on the relative size of the impact on individual markets (relative shift of the market supply curves) and the behavioral responses of producers and consumers in each market (measured by the price elasticities of supply and demand).

5.2.3 *Supply and Demand Elasticities Used in the Market Model*

The market model incorporates behavioral changes based on the price elasticities of supply and demand. The price elasticities used to estimate the economic impacts presented in Section 5.3 are given in Table 5-3. Because most of the direct cost impacts fall on engines involved in the production of natural gas, the price elasticity of supply in the natural gas market is one of the most important factors influencing the size and distribution of the economic impacts associated with the RICE regulation. The supply elasticities in all of the other energy markets also have a significant impact on the results. However, estimates of the elasticity of supply for electric power were unavailable. This is in part because, under traditional regulation, the electric utility industry had a mandate to serve all its customers. In addition, utilities' rates were regulated and were based on allowing them to earn a market rate of return. As a result, the

Table 5-3. Supply and Demand Elasticities

Energy Sectors	Elasticity of Supply	Elasticity of Demand			
		Manufacturing	Commercial[a]	Transportation[a]	Residential[a]
Electricity	0.75	Derived demand	–0.24	–0.24	–0.23
Natural gas	0.41[b]	Derived demand	–0.47	–0.47	–0.26
Petroleum	0.58[b]	Derived demand	–0.28	–0.28	–0.28
Coal	1.0[c]	Derived demand	–0.28	–0.28	–0.28

[a] Energy Information Administration. 2000. "Issues in Midterm Analysis and Forecasting 1999—Table 1." <http://www.eia.doe.gov/oaif/issues/pricetbl1.html>. As obtained on May 8, 2000.
[b] Dahl, Carol, and Thomas E. Dugan. 1996. U.S. Energy Product Supply Elasticities: A Survey and Application to the U.S. Oil Market. *Resource and Energy Economics* 18:243-263.
[c] Zimmerman, M.B. 1977. "Modeling Depletion in the Mineral Industry: The Case of Coal." *The Bell Journal of Economics* 8(2):41-65.

market concept of supply elasticity was not the driving force in utilities' capital investment decisions. However, wholesale market deregulation was initiated by the Energy Policy Act of 1992 and most states have begun to address the issue of retail deregulation. The overall trend is clearly toward deregulation of retail electric markets and the movement is gaining momentum. In future years, the market for electric power will probably look more like a typical competitive industry because of deregulation. To operationalize the model, a supply elasticity of 0.75 was assumed for the electricity market based on an assumption that the supply of electricity is fairly inelastic in the short run.

In contrast, many studies have been conducted on the elasticity of demand for electricity, and it is generally agreed that, in the short run, the demand for electricity is relatively inelastic. Most residential, commercial, and industrial electricity consumers do not significantly adjust short-run behavior in response to changes in the price of electricity. The elasticity of demand for electricity is primarily driven by long-run decisions regarding equipment efficiency and fuel substitution.

Additional elasticity of demand parameters for the residential, commercial, and transportation sectors were obtained from the Energy Information Administration by fuel type (natural gas, petroleum, coal). The demand elasticities also have a very significant impact on the model results. The elasticities of demand for energy are not provided for manufacturing because the model calculates the derived demand from this sector for each of the energy markets modeled based on the estimated output from these markets. In effect, adjustments in the final product markets due to changes in production levels and fuel switching are used to estimate changes in energy demand, eliminating the need for demand elasticity parameters in the energy markets. Supply and demand elasticities for goods and services produced in the industrial and commercial markets are reported in Table 5-4. Appendix B contains a sensitivity analysis for the key supply and demand elasticity assumptions.

5.3 ECONOMIC IMPACT ESTIMATES

This study used a market model to estimate total changes in social welfare and to investigate the distribution of impacts between consumers and producers. In addition, producer impacts are distributed across industries within the energy and manufacturing sectors.

Table 5-5 summarizes the economic impact estimates. The total change in social welfare in 2005 is estimated to be $247.55 million. This estimate includes market adjustments in final product markets and fuel switching adjustments in the manufacturing sector in response to changes in relative prices. For comparison, the baseline engineering costs and social costs without fuel switching are also presented in Table 5-5. Social welfare losses in the model with fuel switching adjustments are $0.02 million less than the estimated baseline engineering costs as a result of behavior changes by producers and consumers that reflect lower cost alternatives.

Table 5-4. Supply and Demand Elasticities for Industrial and Commercial Sectors

NAICS	Description	Supply[a]	Demand[b]
Industrial Sectors			
11	Agricultural Sector	0.75	–1.80
21	Other Mining Sector	0.75	–0.30
23	Construction Sector	0.75	–1.00
311	Food	0.75	–1.00
312	Beverage and Tobacco Products	0.75	–1.30
313	Textile Mills	0.75	–1.50
314	Textile Product Mills	0.75	–1.50
315	Apparel	0.75	–1.10
316	Leather and Allied Products	0.75	–1.20
321	Wood Products	0.75	–1.00
322	Paper	0.75	–1.50
323	Printing and Related Support	0.75	–1.80
325	Chemicals	0.75	–1.80
326	Plastics and Rubber Products	0.75	–1.80
327	Nonmetallic Mineral Products	0.75	–1.00
331	Primary Metals	0.75	–1.00
332	Fabricated Metal Products	0.75	–0.20
333	Machinery	0.75	–0.50
334	Computer and Electronic Products	0.75	–0.30
335	Electrical Equip., Appliances, and Components	0.75	–0.50
336	Transportation Equipment	0.75	–0.50
337	Furniture and Related Products	0.75	–1.80
339	Miscellaneous	0.75	–0.60
Commercial Sector (NAICS 42-45;51-56;61-72)		0.75	–1.00

[a] Assumed supply elasticity. Sensitivity analysis of this assumption is presented in Appendix B.
[b] Source: Personal communication from Larry Sorrels, EPA to Mike Gallaher, RTI. August 15, 2000. Qualitative Market Assessment—PM NAAQS.

Table 5-5. Summary Table

	Change in Social Welfare (Millions of $1998)
Engineering control costs	247.57
Social costs with market adjustments	247.56
Social costs with market adjustments and fuel switching	247.55
Total reporting and record keeping costs	6.15
Total social costs	253.73

Table 5-6 presents the distribution of economic impacts between producers and consumers and shows the distribution of impacts across sectors/markets. The market analysis estimates that consumers will bear a burden of $125.4 million in 2005 (51 percent of the total social cost) because of the increased price of energy, the increased prices of final products, and the smaller quantities of energy and final products generally available. Producer surplus is projected to decrease by $122.1 million in 2005 (49 percent of the total social cost) as a result of the direct control costs, higher energy costs, and reductions in output with the majority of the producer surplus losses logically falling on natural gas producers because the rule applies to engines that are primarily used in natural gas production. The costs to natural gas producers are approximately 29 percent of the total producer surplus loss or 14 percent of the total social cost of the regulation. Producer surplus also falls in the petroleum products market and in each of the final product markets. However, there are energy markets in which producer surplus actually increases as a result of the regulation. In particular, both the electricity and coal markets experience increases in producer surplus. Like natural gas producers, the producers of electricity and coal also face higher input costs due to increases in the price of oil and natural gas. However, the increase in input costs is much less for these producers than the increase in costs applied to natural gas and oil producers. As a result, the supply curve shifts less for electricity and coal than for natural gas and petroleum products, and the price does not increase as much. The fact that the prices of electricity and coal increase less than those of natural gas and

Table 5-6. Distribution of Social Costs

Sectors/Markets		Change in: Producer Surplus	Consumer Surplus	Social Welfare
Energy Markets				
Petroleum (NAICS 32411, 4861)		–$6.0	NA	NA
Natural gas (NAICS 21111, 4862, 2212)		–$35.2	NA	NA
Electricity (NAICS 22111, 221122, 221121)		$3.2	NA	NA
Coal (NAICS 2121)		$0.3	NA	NA
Subtotal		–$38.3	NA	NA
NAICS Code	**Description**			
Industrial Sector				
11	Agricultural Sector	–$1.6	–$0.7	–$2.3
21	Other Mining Sector	–$6.0	–$15.0	–$21.0
23	Construction Sector	–$6.3	–$4.7	–$11.1
311	Food	–$3.4	–$2.5	–$5.9
312	Beverage and Tobacco Products	–$0.6	–$0.3	–$1.0
313	Textiles Mills	–$0.5	–$0.3	–$0.8
314	Textile Product Mills	–$0.1	–$0.1	–$0.2
315	Apparel	–$0.1	–$0.1	–$0.2
316	Leather and Allied Products	–$0.0	–$0.0	–$0.0
321	Wood Products	–$0.3	–$0.3	–$0.6
322	Paper	–$3.5	–$1.7	–$5.2
323	Printing and Related Support	–$0.3	–$0.1	–$0.4
325	Chemicals	–$12.6	–$5.2	–$17.8
326	Plastics and Rubber Products	–$1.5	–$0.6	–$2.1
327	Nonmetalic Mineral Products	–$2.0	–$1.5	–$3.5
331	Primary Metals	–$3.9	–$2.9	–$6.7
332	Fabricated Metal Products	–$0.4	–$1.4	–$1.8
333	Machinery	–$0.3	–$0.5	–$0.8
334	Computer and Electronic Products	–$0.2	–$0.5	–$0.6
335	Electrical Equipment, Appliances, and	–$0.2	–$0.3	–$0.4
336	Transportation Equipment	–$0.7	–$1.0	–$1.7
337	Furniture and Related Products	–$0.2	–$0.1	–$0.2
339	Miscellaneous	–$0.1	–$0.2	–$0.3
Industrial Sector Subtotal		–$44.7	–$39.9	–$84.6
Commercial Sector		–$39.1	–$29.3	–$68.4
Residential Sector		NA	–$40.0	–$40.0
Transportation Sector		NA	–$16.2	–$16.2
Subtotal		–$83.8	–$125.4	–$209.2

petroleum cause electricity and coal to become more attractive to energy consumers because they have become relatively less expensive energy sources following the regulation despite their increase in price. This leads to an increase in the demand for electricity and coal as some consumers switch their fuel usage to consume a smaller proportion of natural gas and petroleum products and a larger proportion of electricity and coal due to the changing incentives facing them as relative prices of energy products change. Consumers change their consumption until the energy markets once again reach equilibrium at new levels of price and output. The increase in demand for electricity and coal resulting from fuel switching by energy users outweighs the increase in input costs and leads to increases in producer surplus in these two markets.

The total welfare loss for the industrial sectors affected by the rule is estimated to total approximately $39.9 million for consumers and $44.7 million for producers in the aggregate, but product prices and output do not show substantial changes. This may occur because in comparison to the projected energy expenditures in these industries (estimated to be $180 billion in 1998 [EIA, 2000]), the cost of this rule to producers as a percentage of their energy expenditures is only 0.06 percent. Also, the total value of shipments for the affected industrial sectors was $5.0 trillion in 1998, so the cost to consumers of these products as a percentage of spending on the outputs from these industries is less than 0.01 percent.

The cost to residential consumers of energy is estimated to be $40.0 million. This cost represents 0.04 percent of the projected annual residential energy expenditures of $111 billion (EIA, 2000). The commercial sector also experiences a large portion of the total social cost with an impact to this sector estimated at $68.4 million. For the commercial sector, energy expenditures are projected to be $92 billion (EIA, 2000c). Therefore, the regulatory burden associated with the RICE MACT is estimated as 0.07 percent of total energy expenditures by the commercial sector. The cost to transportation consumers is estimated by the economic model to be $16.2 million. This cost represents approximately 0.01 percent of energy expenditures for the transportation sector ($16.2 million/$241 billion [EIA, 2000c]).

The equilibrium changes in price and quantity in the energy markets are presented in Table 5-7. In both the petroleum and natural gas markets, output decreases and price increases in response to the direct control costs. These control costs increase the cost of producing these products and decrease the supply, resulting in producer surplus losses of $6.0 million and $35.2 million, respectively. The impacts are greater in the natural gas market because that is where the majority of the affected engines operate. Even with the relatively large cost in the natural gas market, natural gas prices are estimated to increase by only 0.101 percent, while the impacts in the other energy markets are expected to be much smaller as shown in Table 5-7. This increase in the price of natural gas is reasonable given the engineering cost impact on the natural gas market, which is estimated to be 0.132 percent of the initial price, and the increased cost of fuel as an input into producing natural gas for consumption. The total cost impact of these two effects is 0.135 percent of the initial market price of natural gas. The market price is expected to increase by less than the increase in engineering costs and input fuel costs because the economic model allows producers and consumers to change their behavior in response to price changes. As price increases, consumers reduce the quantity that they are willing to purchase. Therefore, if producers attempted to simply increase the price of their product by the full amount that their costs increased, then there would be a surplus of natural gas because consumers would not be willing to continue purchasing the initial quantity at a higher price. Producers would then respond by lowering prices until a new equilibrium is reached to avoid holding excess inventory. The market for petroleum products faces a similar situation. The engineering costs entering the economic model are estimated to be 0.005 percent of the initial price. Adding in the increased costs of energy used in the production of petroleum products, the total cost impact is about 0.007 percent of initial market price, whereas the model results indicate a 0.005 percent increase in the price of petroleum products after taking behavioral responses into account.

In the electricity market, both price and quantity increase slightly (by 0.022 percent and 0.001 percent, respectively), which implies that, although the supply in this market decreases, there is an increase in demand that is larger than the decrease in supply and which leads to a minimal increase in equilibrium quantity. This is presumably due to consumers changing their fuel usage in response to higher prices for natural gas and petroleum. In the petroleum products, natural gas, and electricity markets, the change in price is larger in magnitude than the change in

Table 5-7. Market-Level Impacts

Sectors/Markets		Percent Change: Price	Percent Change: Quantity
Energy Markets			
Petroleum (NAICS 32411, 4861)		0.005%	–0.001%
Natural gas (NAICS 21111, 4862, 2212)		0.101%	–0.0140%
Electricity (NAICS 22111, 221122, 221121)		0.022%	0.001%
Coal (NAICS 2121)		0.001%	0.001%
NAICS Code	**Description**		
Industrial Sectors			
11	Agricultural Sector	0.000%	–0.001%
21	Other Mining Sector	0.020%	–0.006%
23	Construction Sector	0.001%	–0.001%
311	Food	0.001%	–0.001%
312	Beverage and Tobacco Products	0.000%	0.000%
313	Textiles Mills	0.000%	–0.001%
314	Textile Product Mills	0.000%	0.000%
315	Apparel	0.000%	0.000%
316	Leather and Allied Products	0.000%	0.000%
321	Wood Products	0.000%	0.000%
322	Paper	0.001%	–0.001%
323	Printing and Related Support	0.000%	0.000%
325	Chemicals	0.001%	–0.002%
326	Plastics and Rubber Products	0.000%	–0.001%
327	Nonmetalic Mineral Products	0.002%	–0.002%
331	Primary Metals	0.001%	–0.001%
332	Fabricated Metal Products	0.001%	0.000%
333	Machinery	0.000%	0.000%
334	Computer and Electronic Products	0.000%	0.000%
335	Electrical Equipment, Appliances, and	0.000%	0.000%
336	Transportation Equipment	0.000%	0.000%
337	Furniture and Related Products	0.000%	0.000%
339	Miscellaneous	0.000%	0.000%
Commercial Sector		0.000%	0.000%

quantity because demand is more inelastic than supply in these markets, meaning that quantity is relatively unresponsive to changes in price. Price and quantity both increase in the coal market also (by 0.001 percent for both price and quantity), again because of a positive demand shift that outweighs any negative supply shift resulting from an increase in the energy input costs for coal production. Demand from utilities and other consumers is increasing due to switching towards coal usage as well as the increase in output of electricity. Because the primary users of coal are electricity producers and much of the electricity produced in the U.S. is produced at coal burning plants, an increase in the equilibrium quantity of electricity will lead to an increase in the derived demand for coal from the utilities.

Table 5-7 also provides the percentage change in price and quantity for the manufacturing final product markets. The regulation increases the price of final products in all markets and decreases the quantity. The final product markets behave similarly to the petroleum and natural gas markets. In each case, the estimated increase in price is less than the engineering costs facing that particular product market. In general, the changes in price and quality are very small. Only one market has a change in price or quantity greater than or equal to 0.02 percent. That market is mining and the other mining sector (NAICS 21), which has an estimated increase in price of 0.02 percent and an estimated decrease in quantity of 0.006 percent.

Although the impacts on price and quantity in the final product markets are estimated to be small, one possible effect of modeling market impacts at the two- and three-digit NAICS code level is that there may potentially be fuel-intensive industries within the larger NAICS code definition that are affected more significantly than the average for that NAICS code. Thus, the changes in price and quantity should be interpreted as an average for the whole NAICS code, not necessarily for each disaggregated industry within that NAICS code.

These results have some uncertainty associated with them due to assumptions that are made to operationalize the model. A full discussion of these uncertainties is provided in Appendix C.

5.4 CONCLUSIONS

The total social cost estimated using the market analysis is $253.73 million in the year 2005. The economic impact from the market analysis is $0.02 million less than the estimated baseline engineering costs because the market model accounts for behavioral changes of producers and consumers. Although the rule affects engines that are primarily used in the natural gas industry, the natural gas producers incur only 14 percent of the total social cost of the regulation. The burden is spread across numerous markets because the price of energy increases slightly as a result of the regulation, which increases the cost of production for all markets that use energy as part of their production process.

The market model estimates that the regulation will increase the cost of producing petroleum products and natural gas, leading to decreases in the quantity of these products produced and increases in their prices. Because of fuel switching away from natural gas and petroleum and towards electricity and coal taking place, both the electricity and coal markets have increases in demand that outweigh any reduction in supply caused by an increase in input prices. The market analysis also indicates that the impacts of the regulation will be borne primarily by natural gas producers and consumers in the manufacturing, commercial, and residential sectors. The manufacturing markets that are most affected are the other mining sector (NAICS 21), food (NAICS 311), chemicals (NAICS 325), and construction (NAICS 23) markets.

Because of the minimal changes in price and quantity estimated for most of the affected markets, EPA expects that there would be no discernable impact on international trade. Although an increase in the price of U.S. products relative to those of foreign producers is expected to decrease exports and increase imports, the changes in price due to the RICE MACT are generally too small to significantly influence trade patterns. In addition, the market facing the largest increase in price is the natural gas market, but imports of natural gas are essentially limited to Canadian gas, which will also be subject to at least some of the costs of the regulation as it is transported through pipelines in the U.S. There may also be a small decrease in employment, but because the impact of the regulation is spread across so many industries and the decreases in market quantities are so small, it is unlikely that any particular industry will face a significant decrease in employment.

Because of the decrease in the quantity of natural gas and petroleum products projected due to the RICE MACT, as well as the decrease in output in the final product markets, it is expected that fewer new engines will be installed than in the absence of the regulation. Table 5-8 shows the regulation's estimated impact on the number of new engines installed based on a constant number of engines being added per unit of output in each affected market. The manufacturing markets category is the sum of engines used in all 24 manufacturing markets included in this analysis. However, the changes in quantity projected in each of these markets were so small that none of the manufacturing markets were projected to have any reduction in the number of new engines installed. The category labeled "other" contains all of the engines in the commercial market. Because the quantity of output was assumed unchanged in these markets, it is assumed that the number of engines demanded in these sectors will also remain constant. Because the percentage changes in price and quantity are so small, the estimated impact on the number of engines is extremely small. According to the economic model, approximately 2 fewer engines (0.01 percent of the projected total) will be installed due to the regulation because of reductions in output in the natural gas and manufacturing markets.

Table 5-8. Impacts on the Number of New Engines Installed

New Engines	Baseline	With Regulation
Natural gas market	11,581	11,579
Petroleum products market	1,602	1,602
Manufacturing, mining, and agricultural markets	3,405	3,405
Commercial markets	3,721	3,721
Total	**20,309**	**20,307**

6.0 IMPACTS ON FIRMS OWNING RICE UNITS

The regulatory costs imposed on domestic producers to reduce air emissions from internal combustion engines will have a direct impact on owners of the affected facilities. Firms or individuals that own the facilities with internal combustion engines are legal business entities that have the capacity to conduct business transactions and make business decisions that affect the facility. The legal and financial responsibility for compliance with a regulatory action ultimately rests with these owners, who must bear the financial consequences of their decisions. Environmental regulations, such as the proposed internal combustion engine standard, affect both large and small entities (businesses or governments), but small entities may have special problems in complying with such regulations.

The Regulatory Flexibility Act (RFA) of 1980 requires that special consideration be given to small entities affected by federal regulation. Specifically, the RFA requires determining whether a regulation will significantly affect a substantial number of small entities or cause a disproportionate burden on small entities in comparison with large companies. In 1996, the Small Business Regulatory Enforcement Fairness Act (SBREFA) was passed, which further amended the RFA by expanding judicial review of agencies' compliance with the RFA and by expanding small entity review of EPA rulemaking.

This analysis assesses the potential impacts of the standard on small entities. To make this assessment, the costs of the regulation are, to the extent possible, mapped to firm-level data (or government-level data) and proportional cost effects are estimated for each identified firm (or government). Then, the focus is placed on small firms and the question of whether there are a substantial number with a large regulatory cost-to-sales impact. The control costs under the MACT floor are used to estimate cost-to-sales ratios (CSRs).

6.1 IDENTIFYING SMALL BUSINESSES

To support the economic impact analysis of the proposed regulation, EPA identified 26,832 engines located at commercial, industrial, and government facilities. The population of engines was developed from the EPA Industrial Combustion Coordinated Rulemaking (ICCR) Inventory Database version 4.1.[1] The list of engines contained in these databases was developed from information in the AIRS and OTAG databases, state and local permit records, and the combustion source ICR conducted by the Agency. Industry and environmental stakeholders reviewed the units contained in these databases as part of the ICCR FACA process. In addition, stakeholders contributed to the databases by identifying and including omitted units. Information was extracted from the ICCR databases to support the engines NESHAP. This modified database containing information on only engines is referred to as the Inventory Database.

From this initial population of 26,832 engines, 10,118 engines were excluded because the proposed regulation will not cover engines smaller than 500 hp or engines used to supply emergency/backup power. Table 6-1 provides the remaining population of 16,714 engines, broken out by industry SIC code, the format in which the database was originally constructed. Although data used in the economic model was later converted to NAICS, the data presented in this table is by SIC code because there was insufficient data to map units without control costs to the appropriate NAICS code.

Because it is not possible to project specific companies or government organizations that will purchase new engines in the future, the small business screening analysis for the RICE MACT is based on the evaluation of existing owners of engines. It is assumed that the existing

[1]The ICCR Inventory Database contains data for boilers, process heaters, incinerators, landfill gas flares, turbines, and internal combustion engines.

Table 6-1. Unit Counts and Percentages by Industry

Industry (SIC)	Subset Mapped with Control Costs: Number of Units	Subset Mapped with Control Costs: Percentage of Total Units	Inventory Database: Number of Units	Inventory Database: Percentage of Total Units
Agriculture (01-09)	1	0.04	8	0.05
Mining (10-12, 14)	33	1.25	663	3.97
Petroleum & Natural Gas Exploration (13)	1,145	43.29	6,191	37.04
Construction (15-17)	1	0.04	84	0.50
Manufacturing (20-39)	57	2.16	1,547	9.26
Utility Services (40-48)	9	0.34	241	1.44
Electricity & Gas Services (49)	1,306	49.38	6,371	38.12
Wholesale Trade (50-51)	1	0.04	171	1.02
Retail Trade (52-59)	4	0.15	26	0.16
Finance, Real Estate, & Insurance (60-67)	6	0.23	84	0.50
Services (70-89)	50	1.91	331	1.98
Government (90-98)	4	0.15	387	2.32
Not Elsewhere Classified (99)	0		41	0.25
Unknown	28	1.07	670	4.01
Total	2,645		16,714	

size and ownership distribution of engines in the Inventory Database is representative of the future growth in new engines. The remainder of this section presents cost and sales information on small companies and government organizations that own existing engines.

6.2 SCREENING-LEVEL ANALYSIS

To conduct the small entity analysis, unit model numbers (Alpha Gamma Technologies, Inc., 2000) were linked to individual units (engines) at affected facilities so that parent companies' aggregate control costs could be compared to company sales. Of the 16,714 affected units in the Inventory Database, 2,645 units had sufficient information to assign model numbers. Table 6-1 compares the unit counts and percentage of units by industry for the total Inventory Database population and the subset of units used in the small entity analysis.

As indicated in Table 6-1, the subset of units used in the small entity analysis is fairly representative of the population in the Inventory Database because the percentage of units in each SIC code is similar to the percentage in the Inventory Database for most industries. Petroleum & Natural Gas Exploration (NAICS 211) and Electricity & Gas Services (SIC 49/NAICS 221/486) account for the majority of units in both the Inventory Database and subset populations.

6.3 ANALYSIS OF FACILITY-LEVEL AND PARENT-LEVEL DATA

The 2,645 units in the Inventory Database with full information were linked to 834 existing facilities. As shown in Table 6-2, these 834 facilities are owned by 153 parent companies.

Employment and sales are typically used as measures of business size. Employment, sales, and tax revenue data (when applicable) were collected for 141 of the 153 parent companies.[2] Sales and employment information was unavailable for 12 parent companies. Figure 6-1 shows the distribution of employees by parent company. Employment for parent companies ranges from 5 to 96,650 employees. Fifty-eight of the firms have fewer than 500 employees, and seven companies have more than 25,000 employees.

[2]Total annualized cost is compared to tax revenue to assess the relative impact on local governments.

Table 6-2. Facility-Level and Parent-Level Data

NAICS	Industry Description	Number of Facilities	Number of Parent Companies	Average Number of Facilities per Parent Company
112	Animal Production	1	1	1.0
211	Oil and Gas Extraction	312	37	8.4
212	Mining (Except Oil and Gas)	28	16	1.8
221	Utilities	15	9	1.7
234	Heavy Construction	1	1	1.0
311	Food Manufacturing	4	4	1.0
312	Beverage and Tobacco Product Manufacturing	1	0	
322	Paper Manufacturing	1	1	1.0
324	Petroleum and Coal Products Manufacturing	7	5	1.4
325	Chemical Manufacturing	4	3	1.3
326	Plastics and Rubber Products Manufacturing	1	2	0.5
327	Nonmetallic Mineral Product Manufacturing	1	0	
331	Primary Metal Manufacturing	1	1	1.0
421	Wholesale Trade, Durable Goods	1	0	
441	Motor Vehicle and Parts Dealers	1	1	1.0
486	Pipeline Transportation	424	48	8.8
488	Support Activities for Transportation	1	1	1.0
524	Insurance Carriers and Related Activities	3	3	1.0
531	Real Estate	1	1	1.0
541	Professional, Scientific, and Technical Services	1	0	
562	Waste Management and Remediation Services	1	0	
611	Educational Services	1	1	1.0
622	Hospitals	20	17	1.2
922	Justice, Public Order, and Safety Activities	1	1	1.0
Unknown	Industry Classification Unknown	2		
Total		834	153	

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

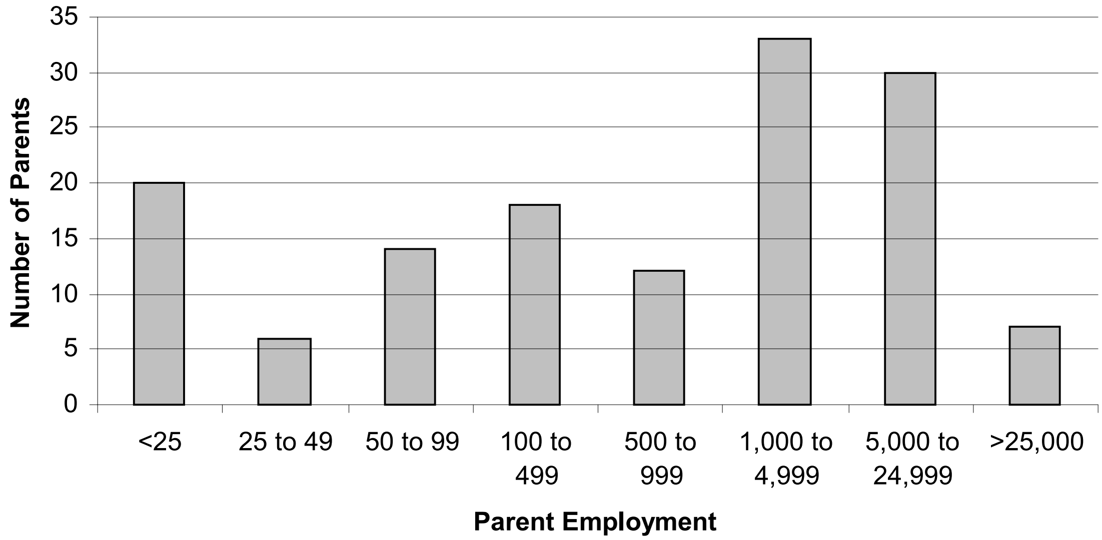


Figure 6-1. Parent Size by Employment Range
Includes 141 parent companies for which data are available.

Sales provide another measure of business size. Figure 6-2 presents the sales distribution for affected parent companies. The median sales figure for affected companies is $300 million, and the average sales figure is $4.7 billion (excluding the federal government). As shown in Figure 6-2, the distribution of firm sales is fairly evenly distributed, but approximately two-thirds of all parent companies have sales greater than $100 million. These figures include all sales associated with the parent company, not just facilities affected by the regulation (i.e., facilities with internal combustion engines).

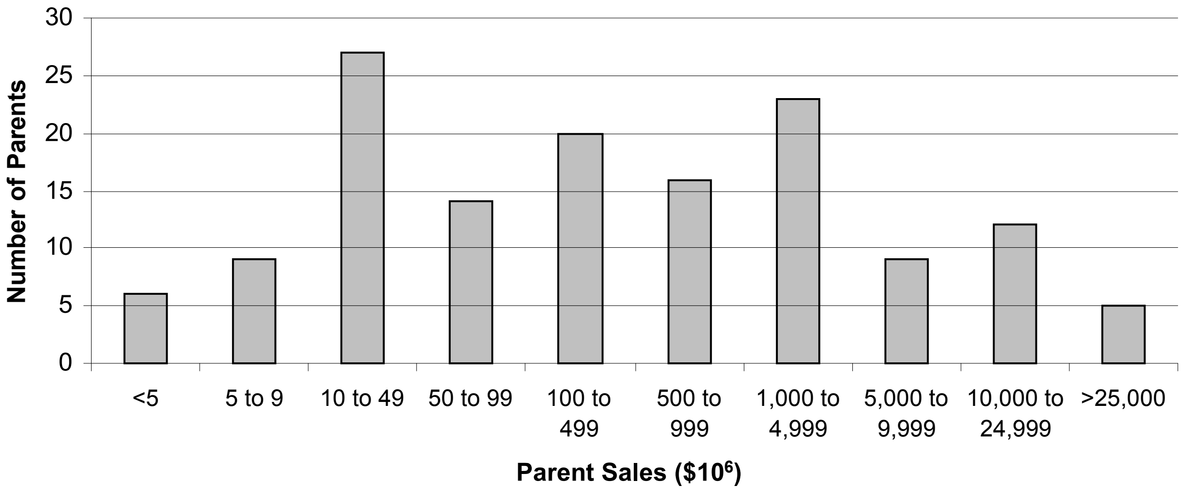


Figure 6-2. Number of Parents by Sales Range
Includes 141 parent companies for which data are available.

Based on Small Business Administration guidelines (SBA, 1999), 47 entities were identified as small. Small businesses by business type are presented in Table 6-3.[3] The oil and gas extraction industry and the mining industry each have 14 small companies. Seven small companies are in the utilities industry and 5 are in pipeline transportation. The remaining small businesses are distributed across seven different three-digit NAICS code groupings. Also, six cities are classified as small governments because they have fewer than 50,000 residents, based on guidelines established by EO 12875.

[3]Small business guidelines typically define small businesses based on employment, and the threshold varies from industry to industry. For example, in the paints and allied products industry, a business with fewer than 500 employees is considered a small business; whereas in the industrial gases industry, a business with fewer than 1,000 employees is considered small. However, for a few industries, usually services, sales are used as the criterion. For example, in the veterinary hospital industry, companies with less than $5 million in annual sales are defined as small businesses.

Table 6-3. Small Parent Companies

NAICS	Industry Description	Number of Facilities	Number of Parent Companies	Number of Small Companies
112	Animal Production	1	1	0
211	Oil and Gas Extraction	312	37	14
212	Mining (Except Oil and Gas)	28	16	14
221	Utilities	15	9	7
234	Heavy Construction	1	1	1
311	Food Manufacturing	4	4	2
312	Beverage and Tobacco Product Manufacturing	1	0	0
322	Paper Manufacturing	1	1	1
324	Petroleum and Coal Products Manufacturing	7	5	2
325	Chemical Manufacturing	4	3	1
326	Plastics and Rubber Products Manufacturing	1	2	0
327	Nonmetallic Mineral Product Manufacturing	1	0	0
331	Primary Metal Manufacturing	1	1	0
421	Wholesale Trade, Durable Goods	1	0	0
441	Motor Vehicle and Parts Dealers	1	1	0
486	Pipeline Transportation	424	48	5
488	Support Activities for Transportation	1	1	0
524	Insurance Carriers and Related Activities	3	3	0
531	Real Estate	1	1	0
541	Professional, Scientific, and Technical Services	1	0	0
562	Waste management and Remediation Services	1	0	0
611	Educational Services	1	1	0
622	Hospitals	20	17	0
922	Justice, Public Order, and Safety Activities	1	1	0
Unknown	Industry Classification Unknown	2		
Total		834	153	47

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

6.4 SMALL BUSINESS IMPACTS

Although there are a total of 47 small entities identified in the Inventory Database, only 13 of them own 4SRB engines. As mentioned in previous sections, the only existing engines affected by the rule are 4SRB units, while all other types of engines will only have requirements on new engines rather than existing units. These small entities own a total of 39 4SRB units at 21 facilities. The impacts on the affected entities in the Inventory Database are summarized in Table 6-4 assuming that each of the 39 4SRB units are located at major sources. This is an upper bound cost scenario because only 40 percent of all RICE units are estimated to be at major sources, and therefore subject to the rule. Based on this percentage, only about 16 of the 39 4SRB units identified at facilities owned by small businesses would be located at major sources. It is reasonable to expect that the percentage of facilities owned by small businesses that are major sources would be lower than the average for the whole source category, so even fewer existing 4SRB owned by small businesses may be affected. However, because it is unknown which facilities are major sources and which are area sources, it was assumed that all existing 4SRB owned by small businesses are located at major sources and subject to the rule to provide a conservative estimate of the small business impacts. Even under this scenario, there are no small firms that have compliance costs above 3 percent of firm revenues and only two small firms owning 4SRB engines that have impacts between 1 and 3 percent of revenues. In addition to twelve small firms with 4SRB engines, there is one small government in the Inventory Database affected by this rule. The costs to this city are approximately $3 per capita annually assuming their engine is affected by the rule, less than 0.01 percent of median household income.

Table 6-4. Summary Statistics for SBREFA Screening Analysis: Existing Affected Small Entities

Total Number of Small Entities		**13[a]**
Average Annual Compliance Cost ($$10^6$/yr)[b]		**$120,067**
Small Entities with Sales/Revenue Datab	Number	Share
Compliance Costs < 1% of sales	10	83.3%
Compliance Costs between 1 and 3% of sales	2	16.7%
Compliance Costs > 3% of sales	0	0.0%
Total	12	100.0%
Compliance Cost-to-Sales Ratios Descriptive Statisticsb		
Average		0.73%
Median		0.58%
Minimum		0.06%
Maximum		2.27%

[a] One of these is a small city for which no sales were available.
[b] Assumes no market responses (i.e., price and output adjustments) by regulated entities and that all of these entities are classified as major sources (upper bound cost scenario).

Based on this subset of the existing engines population, the regulation will affect no small entities owning RICE at a CSR greater than 3 percent, while approximately 4 percent (2/47) of small entities owning RICE greater than 500 hp will have compliance costs between 1 and 3 percent of sales under an upper bound cost scenario. The total existing population of engines with greater than 500 hp that are not backup units is estimated to be 22,018 (Alpha Gamma, 2002a). Assuming the same breakdown of large and small company ownership of engines in the total population of existing engines as in the subset with parent company information identified, the Agency expects that approximately 17 small entities in the existing population of RICE owners would have CSRs between 1 and 3 percent under an upper bound cost scenario where all RICE owned by small entities are located at major sources.

In addition, because many small entities owning RICE will not be affected because of the exclusion of engines with less than 500 hp, the percentage of all small companies owning RICE that are affected by this regulation is even smaller. Based on the proportion of engines in the Inventory Database that are greater than 500 hp and are not backup units (16,714/26,832, or 62.3

percent) and assuming that small companies own the same proportion of small engines (less than 500 hp) as they do of engines greater than 500 hp, the Agency estimates that 628 small companies own RICE. Of all small companies owning RICE, 2.7 percent (17/628) are expected to have CSRs between 1 and 3 percent under an upper bound cost scenario. If the percentage of RICE owned by small companies that are located at major sources is the same as the engine population overall (40 percent), only about 1.1 percent of small companies owning RICE would be expected to have CSRs greater than 1 percent.

6.5 ASSESSMENT OF SMALL ENTITY SCREENING

As outlined above, this regulation will affect only a very small percentage of small entities owning RICE units. To determine whether the impacts on existing small entities are significant, typical profit margins in the affected industries were considered. The engines included in the database are owned and operated in more than 25 different industries, but the majority of the small businesses affected by the proposed regulation are in the oil and gas extraction; mining and quarrying; and electric, gas, and sanitary services sectors (see Table 6-3). As shown in Table 6-5, the average profit margin for these sectors is approximately 5 percent. Table 6-5 also shows the profit margins for the other industry sectors with affected small entities. All profit margins of industry sectors with affected small businesses are above 2 percent. Based on this median profit margin data, it seems reasonable to review the number of small firms with CSRs above 3 percent in screening for significant impacts.

This analysis shows that none of the small entities in the Inventory Database have impacts greater than 5 percent and only two small firms have impacts between 1 and 3 percent even under an upper bound cost scenario. Based on the low number of affected small firms, the fact that no small firms have CSRs between 3 and 5 percent, and the fact that industry profit margins average 5 percent, this analysis concludes that this proposed regulation will not have a significant impact on a substantial number of existing small entities.

For new sources, it can be reasonably assumed that the investment decision to purchase a new engine may be slightly altered as a result of the regulation. For the entire population of affected engines projected to exist in 2005, the economic model predicts 2 fewer engines (0.01 percent of the projected total in the absence of the regulation) will be purchased because of

Table 6-5. Profit Margins for Industry Sectors with Affected Small Businesses

NAICS	Industry Description	Median Profit Margin
212	Metal Mining	5.1%
211	Oil & Gas Extraction	4.6%
212	Mining & Quarrying of Nonmetallic Minerals, Except Fuels	2.1%
234	Heavy Construction	3.5%
311	Food & Kindred Products	3.6%
322	Paper & Allied Products	3.3%
325	Chemicals & Allied Products	2.7%
221/486	Electric, Gas, & Sanitary Services	7.5%

Source: Dun & Bradstreet. 1997. Industry Norms & Key Business Ratios. Desktop Edition 1996-97. Murray Hill, NJ: Dun & Bradstreet, Inc.

market responses to the regulation. Specifically, the slight declines in output in industries that use RICE leads to a small decrease in the number of engines needed to produce that output. It is not feasible, however, to determine future investment decisions at the small entities in the affected industries, so EPA cannot link these 2 engines to any one firm (small or large). Overall, it is very unlikely that a substantial number of small firms who may consider purchasing a new engine will be significantly affected because the decision to purchase new engines is not altered to a large extent. In addition, the rule is likely to increase profits at the many small firms owning RICE that are not affected by the rule by increasing their revenues due to the estimated increase in prices in the energy markets and final product markets.

Although this proposed rule will not have a significant economic impact on a substantial number of small entities, EPA nonetheless has tried to reduce the impact of this rule on small entities. In this proposed rule, the Agency is applying the minimum level of control (i.e., the MACT floor) and the minimum level of monitoring, recordkeeping, and reporting to affected sources allowed by the CAA. In addition, as mentioned earlier in this report, new RICE units with capacities under 500 hp and those that operate as emergency/temporary units are not covered by this proposed rule. This provision should reduce the level of small entity impacts. EPA continues to be interested in the potential impacts of the proposed rule on small entities and welcomes comments on issues related to such impacts.

7.0 QUALITATIVE ASSESSMENT OF BENEFITS OF EMISSION REDUCTIONS

The emission reductions achieved by this environmental regulation will provide benefits to society by improving environmental quality. In this chapter, and the following chapter, information is provided on the types and levels of social benefits anticipated from the RICE NESHAP. This chapter discusses the health and welfare effects associated with the HAPs and other pollutants emitted by RICE. The following chapter places a monetary value of a portion of the benefits that are described here.

In general, the reduction of HAP emissions resulting from the regulation will reduce human and environmental exposure to these pollutants and thus, reduce potential adverse health and welfare effects. This chapter provides a general discussion of the various components of total benefits that may be gained from a reduction in HAPs through this NESHAP. The rule will also achieve reductions of carbon monoxide (CO), nitrous oxides (NOx), and to a lesser extent volatile organic compounds (VOCs) and particulate matter (PM). HAP benefits are presented separately from the benefits associated with other pollutant reductions.

7.1 IDENTIFICATION OF POTENTIAL BENEFIT CATEGORIES

The benefit categories associated with the emission reductions predicted for this regulation can be broadly categorized as those benefits which are attributable to reduced exposure to HAPs, and those attributable to reduced exposure to other pollutants. Some of the HAPs associated with this regulation have been classified as probable human carcinogens. As a result, a potential benefit of the proposed regulation is a reduction in the risk of lung and nasopharyngeal cancer illness and possibly mortality. Other benefit categories include: reduced incidence of neurological effects and irritants associated with exposure to noncarcinogenic HAPs, and reduced incidence of cardiovascular and central nervous system problems associated with CO, and mortality and other morbidity effects associated with NOx (or with NOx as it transforms into PM). In addition to health impacts occurring as a result of reductions in HAP and other pollutant emissions, there are welfare impacts which can also be identified. In general, welfare impacts include effects on crops and other plant life, materials damage, soiling, and acidification of estuaries. Each category is discussed separately in the following section.

7.2 QUALITATIVE DESCRIPTION OF AIR RELATED BENEFITS

The health and welfare benefits of HAPs, CO and NOx reductions are summarized separately in the discussions below. Appendix D also provides greater detail from the epidemiological, animal, and occupational studies that have been conducted for the HAP pollutants. Note that because the level of emission reductions of VOCs and PM are relatively small, we do not provide a description of potential benefits of these pollutants in this chapter (except to the extent that NOx can become PM once it is in the ambient air and result in adverse effects as a PM particle).

7.2.1 *Benefits of Reducing HAP Emissions*

According to baseline emission estimates, this source category currently emits approximately 27,489 tons per year of HAPs at existing sources and it is estimated that by the year 2005, new RICE sources will emit 3,840 tons per year of HAPs. This totals 31,329 tons annually at all RICE sources. The regulation will reduce approximately 5,000 tons of emissions of formaldehyde, acetaldehyde, acrolein, and methanol at new and existing sources by 2005.

Human exposure to HAPs may occur directly through inhalation or indirectly through ingestion of food or water contaminated by HAPs or through dermal exposure. HAPs may also enter terrestrial and aquatic ecosystems through atmospheric deposition. HAPs can be deposited on vegetation and soil through wet or dry deposition. HAPs may also enter the aquatic environment from the atmosphere via gas exchange between surface water and the ambient air, wet or dry deposition of particulate HAPs and particles to which HAPs adsorb, and wet or dry deposition to watersheds with subsequent leaching or runoff to bodies of water (EPA,1992a).

This analysis is focused only on the air quality benefits of HAP reduction. A summary of the range of potential physical health and welfare effects categories that may be associated with HAP emissions is provided in Table 7-1. As noted in the table, exposure to HAPs can lead to a variety of acute and chronic health impacts as well as welfare impacts.

7.2.1.1 *Health Benefits of Reduction in HAP Emissions*.

The HAP emissions reductions achieved by this rule are expected to reduce exposure to ambient concentrations of formaldehyde, acetaldehyde, and methanol, which will reduce a variety of adverse health effects considering both cancer and noncancer endpoints. Formaldehyde and acetaldehyde are classified as probable human carcinogens, according to the *Integrated Risk Information System (IRIS),* an EPA system for reviewing, classifying, and listing chemicals by cancer risk (EPA, 2000c). These HAPs are a concern to EPA because long term exposure to these chemicals have been linked with cases of lung and nasopharyngeal cancer deaths in humans in an occupational setting. Therefore, a reduction in human exposure to formaldehyde and acetaldehyde could lead to a decrease in cancer risk and ultimately to a decrease in cancer illness and mortality.

The remaining species of HAP emitted by RICE, methanol, has not been shown to cause cancer. However, exposure to this pollutant may still result in adverse health impacts to human and non-human populations. In general, noncancer health effects can be grouped into the following broad categories: genotoxicity, developmental toxicity, reproductive toxicity, systemic toxicity, and irritation. *Genotoxicity* is a broad term that usually refers to a chemical that has the ability to damage DNA or the chromosomes. *Developmental toxicity* refers to

Table 7-1. Potential Health and Welfare Effects Associated with Exposure to Hazardous Air Pollutants

Effect Type	Effect Category	Effect End-Point	Citation
Health	Mortality	Carcinogenicity	EPA (1990), Graham et al. (1989)
		Genotoxicity	Graham et al. (1989)
		Non-Cancer lethality	Voorhees et al. (1989)
	Chronic Morbidity	Neurotoxicity	All morbidity end-points obtained from Graham et al. (1989), Voorhees et al. (1989), Cote et al. (1988)
		Immunotoxicity	
		Pulmonary function decrement	
		Liver damage	
		Gastrointestinal toxicity	
		Kidney damage	
		Cardiovascular impairment	
		Hematopoietic (Blood disorders)	
		Reproductive/Developmental toxicity	
	Acute Morbidity	Pulmonary function decrement	
		Dermal irritation	
		Eye irritation	

Table 7-1. Potential Health and Welfare Effects Associated with Exposure to Hazardous Air Pollutants (continued)

Effect Type	Effect Category	Effect End-Point	Citation
Welfare	Materials Damage	Corrosion/Deterioration	NAS (1975)
	Aesthetic	Unpleasant odors Transportation safety concerns	
	Agriculture	Yield reductions/Foliar injury	Stern et al. (1973)
	Ecosystem Structure	Biomass decrease Species richness decline Species diversity decline Community size decrease Organism lifespan decrease Trophic web shortening	Weinstein and Birk (1989)

Source: Mathtech, 1992

adverse effects on a developing organism that may result from exposure prior to conception, during prenatal development, or postnatally to the time of sexual maturation. Adverse developmental effects may be detected at any point in the life span of the organism. *Reproductive toxicity* refers to the harmful effects of HAP exposure on fertility, gestation, or offspring, caused by exposure of either parent to a substance. *Systemic toxicity* affects a portion of the body other than the site of entry. *Irritation*, for the purpose of this document, refers to any effect which results in irritation of the eyes, skin, and respiratory tract (EPA, 1992a). For methanol, IRIS does not present summary data on inhalation effects. IRIS does provide detailed summaries of studies of the effects from oral doses of methanol, but they are not summarized for the purposes of this RIA.

For the HAPs covered by the RICE NESHAP, evidence on the potential toxicity of the pollutants varies. However, given sufficient exposure conditions, each of these HAPs has the potential to elicit adverse health or environmental effects in the exposed populations. It can be expected that emission reductions achieved through the subject NESHAP will decrease the incidence of these adverse health effects.

7.2.1.2 *Welfare Benefits of Reduction in HAP Emissions*.

The welfare effects of exposure to HAPs have received less attention from analysts than the health effects. However, this situation is changing, especially with respect to the effects of toxic substances on ecosystems. Over the past ten years, ecotoxicologists have started to build models of ecological systems which focus on interrelationships in function, the dynamics of stress, and the adaptive potential for recovery. This perspective is reflected in Table 7-1 where the end-points associated with ecosystem functions describe structural attributes rather than species specific responses to HAP exposure. This is consistent with the observation that chronic sub-lethal exposures may affect the normal functioning of individual species in ways that make it less than competitive and therefore more susceptible to a variety of factors including disease, insect attack, and decreases in habitat quality (EPA, 1991). All of these factors may contribute to an overall change in the structure (i.e., composition) and function of the ecosystem.

The adverse, non-human biological effects of HAP emissions include ecosystem, recreational, and commercial fishery impacts. Atmospheric deposition of HAPs directly to land may affect terrestrial ecosystems. Atmospheric deposition of HAPs also contributes to adverse aquatic ecosystem effects. This not only has adverse implications for individual wildlife species and ecosystems as a whole, but also the humans who may ingest contaminated fish and waterfowl. In general, HAP emission reductions achieved through the RICE NESHAP should reduce the associated adverse environmental impacts.

7.2.2 *Benefits of Reducing Other Pollutants Due to HAP Controls*

As is mentioned above, controls that will be required on RICE to reduce HAPs will also reduce emissions of other pollutants, namely: CO, NOx, VOCs, and PM. The adverse effects from CO, NOx, and PM emissions are presented below, but because emission reductions of VOCs are small in magnitude, the effects from these pollutants are not discussed in this analysis.

7.2.2.1 *Benefits of Reduction in Carbon Monoxide Emissions*.

The EPA Staff Paper for carbon monoxide (CO) provides a summary of the health effects information pertinent to the NAAQS for CO (EPA, 2000e). The Staff Paper concludes that human health effects associated with exposure to CO include cardiovascular system and central nervous system (CNS) effects. In addition, consideration is given to combined exposure to CO, other pollutants, drugs, and the influence of environmental factors. Cardiovascular effects of CO are directly related to reduced oxygen content of blood, resulting in tissue hypoxia (i.e., oxygen starvation). Most healthy individuals have mechanisms (e.g., increased blood flow, blood vessel dilation) which compensate for this reduction in tissue oxygen, although the effect of reduced maximal exercise capacity has been reported in some healthy persons. Several other medical conditions such as occlusive vascular disease, chronic obstructive lung disease, and anemia can increase susceptibility to potential adverse effects of CO during exercise. Effects of CO on the CNS involve both behavioral and physiological changes. These include modification of visual perception, hearing, motor and sensorimotor performance, vigilance, and cognitive ability.

Although acute poisoning induced by CO can be lethal and is probably the best known health endpoint of CO, this only occurs at very high concentrations of CO (greater than 100 ppm, hourly average). In the ambient air, exposures to lower-levels of CO predominate and at these levels the best documented adverse health endpoint in human subjects is the decrease in time to onset of reproducible exercise-induced chest pain. Results of some human exposure studies and reports of workers routinely exposed to combustion products provide support for recent epidemiology research suggesting day-to-day variations in ambient CO concentrations are related to cardiovascular hospital admissions and daily mortality, especially for individuals over 65 years of age (EPA, 1999a). Uncertainties about the association between these health endpoints and ambient CO and the relative influence of indoor vs. outdoor CO have not been resolved and will require further research.

There are certain people who are more "at risk" to CO exposures. Individuals with preexisting illness or cardiovascular diseases which limit oxygen absorption or oxygen transport to body tissues would be somewhat more susceptible to the effects of CO. Very little data are available demonstrating human health effects in healthy individuals caused by or associated with exposures to low CO concentrations. Decrements in maximal exercise duration and performance in healthy individuals have been reported, however, these decrements are small and likely to affect only athletes in competition. No effects were seen in healthy individuals during submaximal exercise, representing more typical daily activities. Most recent evidence of CNS effects induced by exposure to CO indicates that behavioral impairments in healthy individuals should not be expected until CO levels are well above what would be caused by typical ambient air levels of CO (EPA, 1999a). Also, evidence of CO-induced fetal toxicity or of interactions with high altitudes, drugs, other pollutants, or other environmental stresses remains uncertain or suggests that effects of concern will occur in healthy individuals only with exposure to very high levels of CO. The Staff Paper concludes that newer health effects evidence published since the last NAAQS review supports the current EPA standards for CO and does not currently support a need for more stringent standards.

7.2.2.2 *Benefits of Reduced Nitrous Oxide Emissions.*

Emissions of NOx produce a wide variety of health and welfare effects (EPA,1999e). Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infection (such as influenza). NOx emissions are an important precursor to acid rain and may affect both terrestrial and aquatic ecosystems. Atmospheric deposition of nitrogen leads to excess nutrient enrichment problems ("eutrophication") in the Chesapeake Bay and several nationally important estuaries along the East and Gulf Coasts. Eutrophication can produce multiple adverse effects on water quality and the aquatic environment, including increased algal blooms, excessive phytoplankton growth, and low or no dissolved oxygen in bottom waters. Eutrophication also reduces sunlight, causing losses in submerged aquatic vegetation critical for healthy estuarine ecosystems. Deposition of nitrogen-containing compounds also affects terrestrial ecosystems. Nitrogen fertilization can alter growth patterns and change the balance of species in an ecosystem.

Nitrogen dioxide and airborne nitrate also contribute to pollutant haze, which impairs visibility and can reduce residential property values and the value placed on scenic views.

NOx in combination with volatile organic compounds (VOC) also serve as precursors to ozone. Based on a large number of recent studies, EPA has identified several key health effects caused when people are exposed to elevated levels of ozone. Short-term exposures (1 to 3 hours) to high ambient ozone concentrations have been linked to increased hospital admissions and emergency room visits for respiratory problems. Repeated exposure to ozone can also make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory disease, such as asthma. Prolonged exposure to ozone can cause repeated inflammation of the lung, impairment of lung defense mechanisms, and irreversible changes in lung structure, which could lead to premature aging of the lungs and/or chronic respiratory illnesses such as emphysema, chronic bronchitis, and chronic asthma.

Children are at most risk from ozone exposure because they typically are active outside playing and exercising, during the summer when ozone levels are highest. Further, children are more at risk than adults from ozone exposure because their respiratory systems are still developing. Adults who are outdoors and moderately active during the summer months, such as construction workers and other outdoor workers, also are among those most at risk. These individuals, as well as people with respiratory illnesses such as asthma, especially children with asthma, can experience reduced lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during periods of moderate exertion. In addition to human health effects, ozone adversely affects crop yield, vegetation and forest growth, and the durability of materials. Ozone causes noticeable foliar damage in many crops, trees, and ornamental plants (i.e., grass, flowers, shrubs, and trees) and causes reduced growth in plants.

Particulate matter (PM) can also be formed from NOx emissions. Secondary PM is formed in the atmosphere through a number of physical and chemical processes that transform gases such as sulfur dioxide, NOx, and VOC into particles. Scientific studies have liked PM (alone or in combination with other air pollutants) with a series of health effects (see Chapter 8 for a detailed discussion of studies used to evaluate health impacts of PM emissions). Coarse particles can accumulate in the respiratory system and aggravate health problems such as asthma. Fine particles penetrate deeply into the lungs and are more likely than coarse particles to contribute to a number of the health effects. These health effects include premature death and increased hospital admissions and emergency room visits, increased respiratory symptoms and disease, decreased lung function, and alterations in lung tissue and structure and in respiratory tract defense mechanisms. Children, the elderly, and people with cardiopulmonary disease, such as asthma, are most at risk from these health effects.

PM also causes a number of adverse effects on the environment. Fine PM is the major cause of reduced visibility in parts of the United States, including many of our national parks and wilderness areas. Other environmental impacts occur when particles deposit onto soil, plants, water, or materials. For example, particles containing nitrogen and sulfur that deposit onto land or water bodies may change the nutrient balance and acidity of those environments, leading to changes in species composition and buffering capacity.

Particles that are deposited directly onto leaves of plants can, depending on their chemical composition, corrode leaf surfaces or interfere with plant metabolism. Finally, PM causes soiling and erosion damage to materials.

Thus, reducing the emissions of NOx from RICE can help to improve some of the effects mentioned above, either those directly related to NOx emissions, or the effects of ozone and PM resulting from the combination of NOx with other pollutants.

7.3 LACK OF APPROVED METHODS TO QUANTIFY HAP BENEFITS

The primary effect associated with the HAPs that are controlled with the proposed rule is the incidence of cancer. In previous analyses of the benefits of reductions in HAPs, EPA has quantified and monetized the benefits of reduced incidences of cancer (EPA, 1992b, 1995). In some cases, EPA has also quantified (but not monetized) reductions in the number of people exposed to non-cancer HAP risks above no-effect levels (EPA, 1995).

Monetization of the benefits of reductions in cancer incidences requires several important inputs, including central estimates of cancer risks, estimates of exposure to carcinogenic HAPs, and estimates of the value of an avoided case of cancer (fatal and non-fatal). In the above referenced analyses, EPA relied on unit risk factors (URF) developed through risk assessment procedures. The unit risk factor is a quantitative estimate of the carcinogenic potency of a pollutant, often expressed as the probability of contracting cancer from a 70 year lifetime continuous exposure to a concentration of one : g/m^3 of a pollutant. These URFs are designed to be conservative, and as such, are more likely to represent the high end of the distribution of risk rather than a best or most likely estimate of risk.

In a typical analysis of the expected health benefits of a regulation (see for example the Heavy Duty Engine/Diesel Fuel Rule's Regulatory Impact Analysis; EPA, 2000d), health effects are estimated by applying changes in pollutant concentrations to best estimates of risk obtained from epidemiological studies. As the purpose of a benefit analysis is to describe the benefits most likely to occur from a reduction in pollution, use of high-end, conservative risk estimates will lead to a biased estimate of the expected benefits of the regulation. For this reason, we will not attempt to quantify the health benefits of reductions in HAPs unless best estimates of risks are available. While we used high-end risk estimates in past analyses, recent advice from the EPA Science Advisory Board and internal methods reviews have suggested that we avoid using high-end estimates in current analyses. EPA is working with the Science Advisory Board to develop better methods for analyzing the benefits of reductions in HAPs. However the methods to conduct a risk analysis of HAP reductions produces high-end estimates of benefits due to assumptions required in such analyses. While we used high-end risk estimates in past analyses, recent advice from the EPA Science Advisory Board (SAB) and internal methods reviews have suggested that we avoid using high-end estimates in current analyses. EPA is working with the SAB to develop better methods for analyzing the benefits of reductions in HAPs. While not appropriate as part of a primary estimate of benefits, to estimate the potential baseline risks posed by the RICE source category and the potential impact of applicability cutoffs discussed in Section 3 of this RIA, EPA performed a "rough" risk assessment, described below. There are large uncertainties regarding all components of the risk quantification step, including location of emission reductions, emission estimates, air concentrations, exposure levels and dose-response relationships. However, if these uncertainties are properly identified and characterized, it is possible to provide estimates of the reduction in inhalation cancer incidence associated with this rule. It is important to keep in mind that these estimates will only cover a very limited portion of the potential HAP effects of the rule, as they exclude non-inhalation based cancer risks and non-cancer health effects.

7.3.1 *Evaluation of Alternative Regulatory Options Based on Risk*

For the RICE source category, four HAP make up the majority of the total HAP. Those four HAP are methanol, formaldehyde, acetaldehyde, and acrolein. Three of these, acetaldehyde, acrolein, and formaldehyde, are included in the HAP listed for the EPA's Urban Air Toxics Program.

The HAP emitted by RICE facilities do not appear on EPA's published lists of compounds believed to be persistent and bioaccumulative.

Two of the HAP, acetaldehyde and formaldehyde, are considered to be non-threshold carcinogens, and cancer potency values are reported for them in IRIS. Acrolein and methanol are not carcinogens, but are considered to be threshold pollutants, and inhalation reference concentrations are reported for them in IRIS and by the California Environmental Protection Agency (CalEPA), respectively.

To estimate the potential baseline risks posed by the RICE source category, EPA performed a crude risk analysis of the RICE source category that focused only on cancer risks. The results of the analysis are based on approaches for estimating cancer incidence that carry significant assumptions, uncertainties, and limitations. Based on the assessment, if this proposed rule is implemented at all affected RICE facilities, annual cancer incidence is estimated to be reduced on the order of ten cases/year. Due to the uncertainties associated with the analysis, annual cancer incidence could be higher or lower than these estimates. (Details of this assessment are available in the docket.)

7.4 SUMMARY

The HAPs that are reduced as a result of implementing the RICE NESHAP will produce a variety of benefits, some of which include: the reduction in the incidence of cancer to exposed populations, neurotoxicity, irritation, and crop or plant damage. The rule will also produce benefits associated with reductions in CO and NOx emissions. Human health effects associated with exposure to CO include cardiovascular system and CNS effects, which are directly related to reduced oxygen content of blood and which can result in modification of visual perception, hearing, motor and sensorimotor performance, vigilance, and cognitive ability. Human health effects associated with NOx include respiratory problems, such as chronic bronchitis, asthma, or even death from complications from PM concentrations created from NOx emissions. Based on this information and the level of reductions anticipated from the RICE NESHAP, the benefits of the rule will be substantial.

8.0 QUANTIFIED BENEFITS

8.1 RESULTS IN BRIEF

In this section, we calculate monetary benefits for the reductions in ambient PM concentrations resulting from the NOx and PM emission reductions expected from the RICE NESHAP. Benefits related to ozone, PM_{10} and $PM_{2.5}$ reductions are calculated using a benefit transfer approach which uses dollar per ton values generated from air quality analyses of NOx and PM emission reductions at RICE facilities. We have used two approaches (Base and Alternative) to provide source benefit estimates from which the benefit transfer values are derived. These approaches differ in their treatment of estimation and valuation of mortality risk reductions and in the valuation of cases of chronic bronchitis. Total benefits (in 1998$) from RICE NOx and PM emission reductions at major sources are presented in Table 8-1.

This benefit analysis does not quantify all potential benefits or disbenefits associated with NOx and PM reductions. This analysis also does not quantify the benefits associated with reductions in hazardous air pollutants. The magnitude of the unquantified benefits associated with omitted categories and pollutants, such as avoided cancer cases, damage to ecosystems, or materials damage to industrial equipment and national monuments, is not known. However, to the extent that unquantified benefits exceed unquantified disbenefits, the estimated benefits presented above will be an underestimate of actual benefits. There are many other sources of uncertainty in the estimates of quantified benefits. These sources of uncertainty, along with the methods for estimating monetized benefits for the RICE NESHAP and a more detailed analysis of the results are presented below.

Table 8-1. Summary of Results:
The Estimated PM and Ozone-Related Benefits of the RICE NESHAP

Estimation Method	Total Benefits[a, b] (millions 1998$)
Base Estimate:	
Using a 3% discount rate	$280 + B
Using a 7% discount rate	$265 + B
Alternative Estimate:	
Using a 3% discount rate	$40 + B
Using a 7% discount rate	$45 + B

[a] Benefits of HAP and CO emission reductions are not quantified in this analysis and, therefore, are not presented in this table. The quantifiable benefits are from emission reductions of NOx and PM only. For notational purposes, unquantified benefits are indicated with a "B" to represent additional monetary benefits. A detailed listing of unquantified NOx, PM, and HAP related health effects is provided in Table 8-13.

[b] Results reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).

8.2 INTRODUCTION

This chapter presents the methods used to estimate the monetary benefits of the reductions in NOx and PM emissions associated with RICE NESHAP controls. Results are presented for the emission controls described in Chapter 2. The benefits that result from the rule include both the Base impacts from application of control technologies or changes in operations and processes, and the secondary effects of the controls. The regulation induced reductions in PM and NOx emissions will result in changes in the physical damages associated with exposure to elevated ambient concentrations of the criteria pollutants, PM and ozone. These damages include changes in both human health and welfare effects categories.

The remainder of this chapter provides the following:

- Subsection 3 provides an overview of the benefits methodology.
- Subsection 4 discusses methods for estimating the NOx and direct PM transfer values used as inputs to the benefits analysis.

- Subsection 5 provides estimates of health and welfare benefits associated with NESHAP controls based on the benefit transfer values and emission reductions.
- Subsection 6 discusses potential benefit categories that are not quantified due to data and/or methodological limitations, and provides a list of analytical uncertainties, limitations, and biases.
- Subsection 7 presents the net benefits (benefits minus costs) of the RICE NESHAP.

8.3 OVERVIEW OF BENEFITS ANALYSIS METHODOLOGY

This section documents the general approach used to estimate benefits resulting from emissions reductions from RICE sources. We follow the basic methodology described in the Regulatory Impact Analysis of the Heavy Duty Engine/Diesel Fuel rule [hereafter referred to as the HDD RIA] (EPA, 2000d).

On September 26, 2002, the National Academy of Sciences (NAS) released a report on its review of the Agency's methodology for analyzing the health benefits of measures taken to reduce air pollution. The report focused on EPA's approach for estimating the health benefits of regulations designed to reduce concentrations of airborne particulate matter (PM).

In its report, the NAS said that EPA has generally used a reasonable framework for analyzing the health benefits of PM-control measures. It recommended, however, that the Agency take a number of steps to improve its benefits analysis. In particular, the NAS stated that the Agency should:

- include benefits estimates for a range of regulatory options;
- estimate benefits for intervals, such as every five years, rather than a single year;
- clearly state the project baseline statistics used in estimating health benefits, including those for air emissions, air quality, and health outcomes;
- examine whether implementation of proposed regulations might cause unintended impacts on human health or the environment;
- when appropriate, use data from non-U.S. studies to broaden age ranges to which current estimates apply and to include more types of relevant health outcomes;

- begin to move the assessment of uncertainties from its ancillary analyses into its Base analyses by conducting probabilistic, multiple-source uncertainty analyses. This assessment should be based on available data and expert judgment.

Although the NAS made a number of recommendations for improvement in EPA's approach, it found that the studies selected by EPA for use in its benefits analysis were generally reasonable choices. In particular, the NAS agreed with EPA's decision to use cohort studies to derive benefits estimates. It also concluded that the Agency's selection of the American Cancer Society (ACS) study for the evaluation of PM-related premature mortality was reasonable, although it noted the publication of new cohort studies that should be evaluated by the Agency.

Several of the NAS recommendations addressed the issue of uncertainty and how the Agency can better analyze and communicate the uncertainties associated with its benefits assessments. In particular, the Committee expressed concern about the Agency's reliance on a single value from its analysis and suggested that EPA develop a probabilistic approach for analyzing the health benefits of proposed regulatory actions. The Agency agrees with this suggestion and is working to develop such an approach for use in future rulemakings.

In this RIA, the Agency has used an interim approach that shows the impact of several important alternative assumptions about the estimation and valuation of reductions in premature mortality and chronic bronchitis. This approach, which was developed in the context of the Agency's Clear Skies analysis, provides an alternative estimate of health benefits using the time series studies in place of cohort studies, as well as alternative valuation methods for mortality and chronic bronchitis risk reductions.

The analysis that follows evaluates the benefits of the RICE NESHAP across four subcategories of control. Only one subcategory will have controls on existing RICE units. For new sources, estimated emission reductions will occur in all subcategories at sources that become operational by 2005. Based on a memo discussing the distribution of major and area sources of RICE units (Alpha-Gamma, 2001a), we anticipate that at least 60 percent of the stationary RICE in operation in 2005 will be located at area sources which are not affected by this regulatory action. Therefore, this analysis presents the benefits of emission reductions occurring at major sources only (i.e., for the 40 percent of the total estimate of emissions at all RICE units in 2005).

The location of new sources is not known. Based on 1996 emissions inventory data, we find NOx emissions from RICE sources to occur throughout the U.S. As such, we also expect the operation of new RICE units in 2005 to be spread across the country. Due to the limitations in availability of data on location of emission reductions from specific RICE sources, this benefits analysis is based on benefit transfer, rather than on modeling of changes in air quality and health effects from the location specific emissions reductions achieved under the RICE NESHAP. Although the NESHAP regulation is expected to result in reductions in emissions of many hazardous air pollutants as well as NOx and PM, benefit transfer values are generated for only NOx and PM due to limitations in availability of transfer values, concentration-response functions, or air quality and exposure models. For this analysis, we focus on directly emitted PM, and NOx in its role as a precursor in the formation of ambient ozone and particulate matter. Other potential impacts of PM and NOx reductions not quantified in this analysis, as well as potential impacts of HAP reductions are described in Chapter 7.

The general term "benefits" refers to any and all outcomes of the regulation that contribute to an enhanced level of social welfare. In this case, the term "benefits" refers to the dollar value associated with all the expected positive impacts of the regulation, that is, all regulatory outcomes that lead to higher social welfare. If the benefits are associated with market goods and services, the monetary value of the benefits is approximated by the sum of the predicted changes in consumer (and producer) "surplus." These "surplus" measures are standard and widely accepted measures in the field of applied welfare economics, and reflect the degree of well-being enjoyed by people given different levels of goods and prices. If the benefits are non-market benefits (such as the risk reductions associated with environmental quality improvements), however, other methods of measuring benefits must be used. In contrast to market goods, non-market goods such as environmental quality improvements are public goods, whose benefits are shared by many people. The total value of such a good is the sum of the dollar amounts that all those who benefit are willing to pay.

Given the current limitations on availability of data on facility-specific emission reductions, we have selected benefit transfer as the most appropriate methodology for this benefits analysis. Benefit transfer is the process of applying quantified benefits derived for a study scenario to a policy scenario for which quantified benefits are desired. This is particularly useful when time or data constraints do not allow for direct and complete quantification of benefits. The benefit transfer value is typically expressed as dollar or health effect benefits per ton of emissions reduced. The PM value per ton can be determined by examining the direct health impacts of changes in ambient PM. To estimate the value per ton of NOx reduced, we need estimates of the value per ton of NOx as an ozone precursor and as a PM precursor. We apply two different approaches to benefit transfer for PM and ozone related benefits, due to differences in availability of data and models. Our approach to benefit transfer for PM related benefits is to generate a benefits analysis for an emissions control scenario similar to the RICE NESHAP scenario, calculate a dollar per ton estimate based on this analysis, and apply that estimate to the emissions reductions expected to result from the NESHAP controls. Our approach for ozone-related benefits is to use a dollar per ton estimate generated from a previous ozone related benefits analyses of NOx reductions from utility and industrial combustion sources. The difference in approach for ozone and PM benefits is due to the fact that a suitable PM air quality model is available, while a suitable ozone model is not.

Development of a benefit transfer value for each criteria pollutant requires selection of an existing set of air quality modeling results that, to the extent possible, parallels the air quality modeling that would be conducted for the current policy if the data and resources were available. This requires review of the magnitude, type, and geographic distribution of emissions reductions used in the air quality analyses, the regions of analysis, and the ambient pollutants modeled in the analyses. Once an existing set of air quality modeling results has been selected, two pieces of information need to be extracted from the results: (1) changes in ambient concentrations of the pollutant, i.e., ozone and (2) reductions in precursor emissions of the pollutant of interest, i.e., NOx. These data, along with the set of concentration-response functions and valuation functions, constitute the input set for the benefit transfer value function. The benefit transfer function for pollutant i is specified as:

The numerator in the transfer value formula is total monetary benefits, which is determined by applying economic valuation functions to changes in incidences of health and welfare endpoints and summing over all endpoints. Changes in incidences of health and welfare endpoints are calculated by applying epidemiological concentration-response functions to the changes in ambient concentrations of the pollutant.

Using the estimated benefit transfer values, national benefits for PM and NOx reductions can be obtained using the following formula:

$$(8.2) \qquad TotalBenefits = TV_{ozone} \bullet \Delta Nox_{ozone} + TV_{PM_{25}} \bullet \Delta NOx_{PM} + TV_{directPM} \bullet \Delta_{directPM}$$

where TV_{ozone} is the transfer value for ozone, TV_{PM} is the transfer value for PM, $TV_{directPM}$ is the transfer value for directly emitted PM,) NOx_{ozone} is the change in NOx ozone precursor emissions,) NOx_{PM} is the change in NOx PM precursor emissions, and) directPM is the change in direct PM emissions. The relevant NOx emission changes for ozone formation are those occurring during the summer ozone season, while those for PM formation are year round.

$$(TransferValue)_t = \frac{Benefits_t}{(Emission\ Re\,ductions)_t}$$

8.3.1 *Methods for Estimating Benefits from Air Quality Improvements*

Environmental and health economists have a number of methods for estimating the economic value of improvements in (or deterioration of) environmental quality. The method used in any given situation depends on the nature of the effect and the kinds of data, time, and resources that are available for investigation and analysis. This section provides an overview of the methods we selected to monetize the benefits included in this RIA.

We note at the outset that EPA rarely has the time or resources to perform extensive new research in the form of evaluating the response in human health effects from specific changes in the concentration of pollutants, or by issuing surveys to collect data of individual's willingness to pay for a particular rule's given change in air quality, which is needed to fully measure the economic benefits of individual rulemakings. As a result, our estimates are based on the best available methods of benefit transfer from epidemiological studies and studies of the economic value of reducing certain health and welfare effects. Benefit transfer is the science and art of adapting Base benefits research on concentration-response functions and measures of the value individuals place on an improvement in a given health effect to the scenarios evaluated for a particular regulation. Thus, we strive to obtain the most accurate measure of benefits for the environmental quality change under analysis given availability of current, peer reviewed research and literature. Where appropriate, adjustments are made for the sociodemographic and economic characteristics of the affected population, and other factors in order to improve the accuracy and robustness of benefits estimates.

In general, economists tend to view an individual's willingness-to-pay (WTP) for an improvement in environmental quality as the most complete and appropriate measure of the value of an environmental or health risk reduction. An individual's willingness-to-accept (WTA) compensation for not receiving the improvement is also a valid measure. Willingness to pay and Willingness to accept are comparable measures when the change in environmental quality is small and there are reasonably close substitutes available. However, WTP is generally considered to be a more readily available and conservative (i.e. more likely to underestimate than overestimate) measure of benefits. Adoption of WTP as the measure of value implies that the value of environmental quality improvements is dependent on the individual preferences of the affected population and that the existing distribution of income (ability to pay) is appropriate.

For many goods, WTP can be observed by examining actual market transactions. For example, if a gallon of bottled drinking water sells for one dollar, it can be observed that at least some persons are willing to pay one dollar for such water. For goods not exchanged in the market, such as most environmental "goods," valuation is not as straightforward. Nevertheless, a value may be inferred from observed behavior, such as sales and prices of products that result in similar effects or risk reductions, (e.g., non-toxic cleaners or bike helmets). Alternatively, surveys may be used in an attempt to directly elicit WTP for an environmental improvement.

One distinction in environmental benefits estimation is between "use values" and "non-use values." Although no general agreement exists among economists on a precise distinction between the two, the general nature of the difference is clear. Use values are those aspects of environmental quality that affect an individual's welfare more or less directly. These effects include changes in product prices, quality, and availability, changes in the quality of outdoor recreation and outdoor aesthetics, changes in health or life expectancy, and the costs of actions taken to avoid negative effects of environmental quality changes.

Non-use values are those for which an individual is willing to pay for reasons that do not relate to the direct use or enjoyment of any environmental benefit, but might relate to existence values and bequest values. Non-use values are not traded, directly or indirectly, in markets. For this reason, the measurement of non-use values has proved to be significantly more difficult than the measurement of use values. The air quality changes produced by this NESHAP cause changes in both use and non-use values, but the monetary benefit estimates are almost exclusively for use values.

More frequently than not, the economic benefits from environmental quality changes are not traded in markets, so direct measurement techniques can not be used. Avoided cost methods are ways to estimate the costs of pollution by using the expenditures made necessary by pollution damage. For example, if buildings must be cleaned or painted more frequently as levels of PM increase, then the appropriately calculated increment of these costs is a reasonable lower bound estimate (under most conditions) of true economic benefits when PM levels are reduced. Avoided costs methods are used to estimate some of the health-related benefits related to morbidity, such as hospital admissions (see the HDD RIA for a detailed discussion of methods to value benefit categories).

Indirect market methods can also be used to infer the benefits of pollution reduction. The most important application of this technique for our analysis is the calculation of the value of a statistical life for use in the estimate of benefits from mortality reductions. There exists no market where changes in the probability of death are directly exchanged. However, people make decisions about occupation, precautionary behavior, and other activities associated with changes in the risk of death. By examining these risk changes and the other characteristics of people's choices, it is possible to infer information about the monetary values associated with changes in mortality risk (see Section 8.4). For measurement of health benefits, this analysis captures the WTP for most use and non-use values, with the exception of the value of avoided hospital admissions, which only captures the avoided cost of illness because no WTP values were available in the published literature.

8.3.2 *Quantifying Individual Health Effect Endpoints*

We use the term "endpoints" to refer to specific effects that can be associated with changes in air quality. To estimate these endpoints, EPA combines changes in ambient air quality levels with epidemiological evidence about population health response to pollution exposure. The most significant monetized benefits of reducing ambient concentrations of ozone and PM are attributable to reductions in human health risks. EPA's Criteria Documents for ozone and PM list numerous health effects known to be linked to ambient concentrations of the pollutants (EPA, 1996a; EPA, 1996b). Chapter 7 described some of these effects. This section describes methods used to quantify and monetize changes in the expected number of incidences of various health effects.

The specific ozone and PM endpoints that are evaluated in this analysis include:

- Premature mortality
- Bronchitis - chronic and acute
- Hospital admissions - respiratory and cardiovascular
- Emergency room visits for asthma
- Asthma attacks
- Acute respiratory symptoms
- Lower and upper respiratory illness
- Decreased worker productivity
- Minor restricted activity days
- Work loss days

As is discussed previously, this analysis relies on concentration-response (C-R) functions estimated in published epidemiological studies relating health effects to ambient air quality. The specific studies from which C-R functions are drawn are included in Table 8-2. Because we rely on methodologies used in prior benefit analyses, a complete discussion of the C-R functions used for this analysis and information about each endpoint are contained in the HDD RIA and in the benefits Technical Support Document for the RIA of the Heavy Duty Engine/Diesel Fuel rule [hereafter referred to as the HDD TSD] (Abt Associates, 2000).

While a broad range of serious health effects have been associated with exposure to elevated ozone and PM levels (described more fully in the EPA's ozone and PM Criteria Documents), we include only a subset of health effects in this quantified benefit analysis. Health effects are excluded from this analysis for four reasons: (i) the possibility of double counting (such as hospital admissions for specific respiratory diseases); (ii) uncertainties in applying effect relationships based on clinical studies to the affected population; (iii) a lack of an established C-R relationship; or (iv) lack of resources to estimate some endpoints.

Using the C-R functions derived from the studies cited in this table, we apply that same C-R relationship to all locations in the United States. Although the C-R relationship may in fact vary somewhat from one location to another (for example, due to differences in population susceptibilities or differences in the composition of PM), location-specific C-R functions are generally not available. A single function applied everywhere may result in overestimates of incidence changes in some locations and underestimates in other locations, but these location-specific biases will, to some extent, cancel each other out when the total incidence change is calculated. It is not possible to know the extent or direction of the bias in the total incidence change based on the general application of a single C-R function everywhere.

Table 8-2. Health Outcomes and Studies Included in the Analysis

Health Outcome	Pollutant	Applied Population	Source of Effect Estimate	Source of Baseline Incidence
Premature Mortality				
All-cause premature mortality from long-term exposure (Base Estimate)	$PM_{2.5}$	> 29 years	Krewski et al., 2000	U.S. Centers for Disease Control, 1999
Short-term exposure (Alternative Estimate)	$PM_{2.5}$	< 65 years, $65 years All ages	Schwartz et al. (1996) Schwartz et al. (2000)	U.S. Centers for Disease Control, 1999
Short-term exposure (Alternative Estimate)	PM_{10}	All ages	Samet et al. (2000) Schwartz et al. (2000)	U.S. Centers for Disease Control, 1999
Chronic Illness				
Chronic Bronchitis (pooled estimate)	$PM_{2.5}$ PM_{10}	> 26 years > 29 years	Abbey et al., 1995 Schwartz et al., 1993	Abbey et al., 1993 Abbey et al., 1993 Adams and Marano, 1995
Hospital Admissions				
All Respiratory	Ozone	Pooled estimate (8 studies)	All ages	
COPD	PM_{10}	> 64 years	Samet et al., 2000	Graves and Gillum, 1997
Pneumonia	PM_{10}	> 64 years	Samet et al., 2000	Graves and Gillum, 1997
Asthma	$PM_{2.5}$	< 65 years	Sheppard et al., 1999	Graves and Gillum, 1997
Total Cardiovascular	PM_{10}	> 64 years	Samet et al., 2000	Graves and Gillum, 1997
Asthma-Related ER Visits	PM_{10}	All ages	Schwartz et al., 1993	Smith et al., 1997 Graves and Gillum, 1997
Other Effects				
Any of 19 Acute Symptoms	Ozone	All ages	Thurston et al., 1992	
Asthma Attacks	PM_{10}	Asthmatics, all ages	Whittemore and Korn, 1980	Krupnick, 1988 Adams and Marano, 1995
Acute Bronchitis	$PM_{2.5}$	Children, 8-12 years	Dockery et al., 1996	Adams and Marano, 1995
Upper Respiratory Symptoms	PM_{10}	Asthmatic children, 9-11	Pope et al., 1991	Pope et al., 1991
Lower Respiratory Symptoms	$PM_{2.5}$	Children, 7-14 years	Schwartz et al., 1994	Schwartz et al., 1994
Decreased Worker Productivity	Ozone		Crocker and Horst, 1981; EPA, 1994	
Work Loss Days	$PM_{2.5}$	Adults, 18-65 years	Ostro, 1987	Adams and Marano, 1995

Health Outcome	Pollutant	Applied Population	Source of Effect Estimate	Source of Baseline Incidence
Minor Restricted Activity Days (minus asthma attacks)	$PM_{2.5}$	Adults, 18-65 years	Ostro and Rothschild., 1989	Ostro and Rothschild, 1989

Recently, the Health Effects Institute (HEI) reported findings by investigators at Johns Hopkins University and others that have raised concerns about aspects of the statistical methodology used in a number of recent time-series studies of short-term exposures to air pollution and health effects (Greenbaum, 2002a). Some of the concentration-response functions used in this benefits analysis were derived from such short-term studies. The estimates derived from the long-term mortality studies, which account for a major share of the benefits in the Base Estimate, are not affected. As discussed in HEI materials provided to sponsors and to the Clean Air Scientific Advisory Committee (Greenbaum, 2002a, 2002b), these investigators found problems in the default "convergence criteria" used in Generalized Additive Models (GAM) and a separate issue first identified by Canadian investigators about the potential to underestimate standard errors in the same statistical package.[1] These and other investigators have begun to reanalyze the results of several important time series studies with alternative approaches that address these issues and have found a downward revision of some results. For example, the mortality risk estimates for short-term exposure to PM_{10} from NMMAPS were overestimated (the C-R function based on the NMMAPS results used in this benefits analysis uses the revised NMMAPS results).[2] However, both the relative magnitude and the direction of bias introduced by the convergence issue is case-specific. In most cases, the concentration-response relationship may be overestimated; in other cases, it may be underestimated. The preliminary renalyses of the mortality and morbidity components of NMMAPS suggest that analyses reporting the lowest relative risks appear to be affected more greatly by this error than studies reporting higher relative risks (Dominici et al., 2002; Schwartz and Zanobetti, 2002).

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[1]Most of the studies used a statistical package known as "S-plus." For further details, see http://www.healtheffects.org/Pubs/NMMAPSletter.pdf.

[2]HEI sponsored the multi-city the National Morbidity, Mortality, and Air Pollution Study (NMMAPS). See http://biosun01.biostat.jhsph.edu/~fdominic/NMMAPS/nmmaps-revised.pdf for revised mortality results.

Our examination of the original studies used in this analysis finds that the health endpoints that are potentially affected by the GAM issues include: reduced hospital admissions and reduced lower respiratory symptoms in the both the Base and Alternative Estimates; reduced lower respiratory symptoms in both the Base and Alternative Estimates; and reduced premature mortality due to short-term PM_{10} exposures in the Base Estimate[3] and reduced premature mortality due to short-term $PM_{2.5}$ exposures in the Alternative Estimate. While resolution of these issues is likely to take some time, the preliminary results from ongoing reanalyses of some of the studies used in our analyses (Dominici et al., 2002; Schwartz and Zanobetti, 2002; Schwartz, personal communication, 2002) suggest a more modest effect of the S-plus error than reported for the NMMAPS PM_{10} mortality study. While we wait for further clarification from the scientific community, we have chosen not to remove these results from the RICE NESHAP benefits estimates, nor have we elected to apply any interim adjustment factor based on the preliminary reanalyses. EPA will continue to monitor the progress of this concern, and make appropriate adjustments as further information is made available.

8.3.2.1 *Concentration-Response Functions for Premature Mortality*

Both long and short-term exposures to ambient levels of air pollution have been associated with increased risk of premature mortality. The size of the mortality risk estimates from these epidemiological studies, the serious nature of the effect itself, and the high monetary value ascribed to prolonging life make mortality risk reduction the most important health endpoint quantified in this analysis. Because of the importance of this endpoint and the considerable uncertainty among economists and policymakers as to the appropriate way to value reductions in mortality risks, this section discusses some of the issues surrounding the estimation of premature mortality. For additional discussion on mortality and issues related to estimating risk for other health effects categories, we refer readers to the discussions presented in EPA's Heavy-Duty Engine/Diesel Fuel RIA (EPA, 2000d).

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[3]Note that in the Base Estimate, reduced premature mortality from long-term $PM_{2.5}$ accounts for a large majority of total monetized benefits. Therefore, although benefits from PM_{10}-related short-term mortality are affected by the GAM issue, total benefits in the Base Estimate are not greatly altered by the affect of this issue on PM_{10}.

Health researchers have consistently linked air pollution, especially PM, with excess mortality. Although a number of uncertainties remain to be addressed by continued research (NRC, 1998), a substantial body of published scientific literature recognizes a correlation between elevated PM concentrations and increased mortality rates. Two types of community epidemiological studies (involving measures of short-term and long-term exposures and response) have been used to estimate PM/mortality relationships. Short-term studies relate short-term (often day-to-day) changes in PM concentrations and changes in daily mortality rates up to several days after a period of elevated PM concentrations. Long-term studies examine the potential relationship between longer-term (e.g., one or more years) exposure to PM and annual mortality rates. Researchers have found significant associations using both types of studies.

<u>Base Estimate</u>

Over a dozen studies have found significant associations between measures of long-term exposure to PM and elevated rates of annual mortality (e.g., Lave and Seskin, 1977; Ozkaynak and Thurston, 1987). While most of the published studies found positive (but not always significant) associations with available PM indices such as total suspended particles (TSP), fine particles components (i.e., sulfates), and fine particles, exploration of alternative model specifications sometimes found inconsistencies (e.g., Lipfert, 1989). These early "cross-sectional" studies were criticized for a number of methodological limitations, particularly for inadequate control at the individual level for variables that are potentially important in causing mortality, such as wealth, smoking, and diet. More recently, several new long-term studies have been published that use improved approaches and appear to be consistent with the earlier body of literature. These new "prospective cohort" studies reflect a significant improvement over the earlier work because they include information on individuals with respect to measures related to health status and residence. The most extensive study and analyses has been based on data from two prospective cohort groups, often referred to as the Harvard "Six-City study" (Dockery et al., 1993) and the "American Cancer Society or ACS study" (Pope et al., 1995); these studies have found consistent relationships between fine particle indicators and mortality across multiple locations in the United States. A third major data set comes from the California based 7^{th} day Adventist study (e.g., Abbey et al., 1999), which reported associations between long-term PM exposure and mortality in men. Results from this cohort, however, have been inconsistent and the air quality results are not geographically representative of most of the U.S. More recently, a cohort of adult male veterans diagnosed with hypertension has been examined (Lipfert et al., 2000). Unlike previous long-term analyses, this study found some associations between mortality and ozone but found inconsistent results for PM indicators.

Given their consistent results and broad applicability to general U.S. populations, the Six-City and ACS data have been of particular importance in benefits analyses. The credibility of these two studies is further enhanced by the fact that they were subject to extensive reexamination and reanalysis by an independent scientific analysis team (Krewski et al., 2000). The final results of the reanalysis were then independently peer reviewed by a Special Panel of the HEI Health Review Committee. The results of these analyses confirmed and expanded those of the original investigators. This intensive independent reanalysis effort was occasioned both by the importance of the original findings as well as concerns that the underlying individual health effects information has never been made publicly available. The HEI re-examination lends credibility to the original studies but also found unexpected sensitivities concerning (a) which pollutants are most important, (b) the role of education in mediating the association between pollution and mortality, and (c) the magnitude of the association depending on how spatial correlation was handled. Further confirmation and extension of the overall findings using more recent air quality and ACS health information was recently published in the *Journal of the American Medical Association* (Pope et al., 2002). In general, the risk estimates based on the long-term mortality studies are substantially greater than those derived from short-term studies.

In developing and improving the methods for estimating and valuing the potential reductions in mortality risk over the years, EPA has consulted with a panel of the Science Advisory Board. That panel recommended use of long-term prospective cohort studies in estimating mortality risk reduction (EPA-SAB-COUNCIL-ADV-99-005, 1999c). More specifically, the SAB recommended emphasis on Pope et al. (1995) because it includes a much larger sample size and longer exposure interval, and covers more locations (50 cities as compared to 6 cities in the Harvard data) than other studies of its kind. As explained in the regulatory impact analysis for the Heavy-Duty Engine/Diesel Fuel rule (EPA, 2000d), more recent EPA benefits analyses have relied on an improved specification from this data set that was developed in the HEI reanalysis of this study (Krewski et al., 2000). The particular specification estimated a C-R function based on changes in mean levels of $PM_{2.5}$, as opposed to the function in the original study, which used median levels. This specification also includes a broader geographic scope than the original study (63 cities versus 50). The SAB has recently agreed with EPA's selection of this specification for use in analyzing mortality benefits of PM reductions (EPA-SAB-COUNCIL-ADV-01-004, 2001). For these reasons, the present analysis uses the same C-R function in developing the Base Estimate of mortality benefits related to fine particles.

Our Base estimate also accounts for a lag between reductions in PM 2.5 concentrations and reductions in mortality incidence. It is currently unknown whether there is a time lag (a delay between changes in PM exposures and changes in mortality rates) in the long-term PM2.5/premature mortality relationship. The existence of such a lag is important for the valuation of premature mortality incidences because economic theory suggests that benefits occurring in the future should be discounted. Although there is no specific scientific evidence of the existence or structure of a PM effects lag, current scientific literature on adverse health effects, such as those associated with PM (e.g., smoking-related disease) and the difference in the effect size between chronic exposure studies and daily mortality studies suggest that all incidences of premature mortality reduction associated with a given incremental change in PM exposure probably would not occur in the same year as the exposure reduction. This same smoking-related literature implies that lags of up to a few years are plausible. Adopting the lag structure used in the Tier 2/Gasoline Sulfur RIA, the HDD RIA, and endorsed by the SAB (EPA-SAB-COUNCIL-ADV-00-001, 1999), we assume a five-year lag structure, with 25 percent of premature deaths occurring in the first year (in 2005), another 25 percent in the second year, and 16.7 percent in each of the remaining three years. The mortality incidences across the 5-year period is then discounted back to our year of analysis, 2005.

For reductions in direct emissions of PM_{10}, we use a different C-R function, based on the studies of mortality and shorter term exposures to PM. Long-term studies of the relationship between chronic exposure and mortality have not found significant associations with coarse particles or total PM_{10}. As discussed earlier in this chapter, concerns have recently been raised about aspects of the statistical methodology used in a number of recent time-series studies of short-term exposures to air pollution and health effects. Due to the “S-Plus” issue identified by the Health Effects Institute, we use as the basis for the Base estimate the revised relative risk from the NMMAPS study, reported on the website of the Johns Hopkins School of Public Health (2002) [4]. Similar to the $PM_{2.5}$ lag adjustment discussed above, we also include an adjustment for PM_{10} to account for recent evidence that daily mortality is associated with particle levels from a number of previous days. We use the overall pooled NMMAPS estimate of a 0.224 percent increase in mortality for a 10 :g/m3 increase in PM_{10} as the starting point in developing our C-R function. In a recent analysis, Schwartz (2000) found that elevated levels of PM_{10} on a given day can elevate mortality on a number of following days. This type of multi-day model is often referred to as a “distributed lag” model because it assumes that mortality following a PM event will be distributed over a number of days following or “lagging” the PM event[5]. Because the NMMAPS study reflects much broader geographic coverage (90 cities) than the Schwartz study (10 cities), and the Schwartz study has not been reanalyzed to account for the “S-Plus” issue, we choose to apply an adjustment based on the Schwartz study to the NMMAPS study to reflect the effect of a distributed lag model.

The distributed lag adjustment factor is constructed as the ratio of the estimated coefficient from the unconstrained distributed lag model to the estimated coefficient from the single-lag model reported in Schwartz (2000). The unconstrained distributed lag model coefficient estimate is 0.0012818 and the single-lag model coefficient estimate is 0.0006479. The ratio of these estimates is 1.9784. This adjustment factor is then multiplied by the revised estimated coefficients from the NMMAPS study. The NMMAPS coefficient corresponding to the 0.224 percent increase in mortality risk is 0.000224. The adjusted NMMAPS coefficent is then 0.000224*1.9784 = 0.000444.

<u>Alternative Estimate</u>

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[4] Available at http://www.biostat.jhsph.edu/biostat/research/update.main.htm.

[5] Both the single day and distributed lag models are likely to be affected to the same degree by the S-Plus convergence issue. As such, the ratio of the coefficients from the models should not be affected as much by any changes in the coefficient.

To reflect concerns about the inherent limitations in the number of studies supporting a causal association between long-term exposure and mortality, an Alternative benefit estimate was derived from the large number of time-series studies that have established a likely causal relationship between short-term measures of PM and daily mortality statistics. A particular strength of such studies is the fact that potential confounding variables such as socio-economic status, occupation, and smoking do not vary on a day-to-day basis in an individual area. A number of multi-city and other types of studies strongly suggest that these effects-relationships cannot be explained by weather, statistical approaches, or other pollutants. The risk estimates from the vast majority of the short-term studies include the effects of only one or two-day exposure to air pollution. More recently, several studies have found that the practice of examining the effects on a single day basis may significantly understate the risk of short-term exposures (Schwartz, 2000; Zanobetti et al., 2002). These studies suggest that the short-term risk can double when the single-day effects are combined with the cumulative impact of exposures over multiple days to weeks prior to a mortality event.

The fact that the PM-mortality coefficients from the cohort studies are far larger than the coefficients derived from the daily time-series studies provides some evidence for an independent chronic effect of PM pollution on health. Indeed, the Base Estimate presumes that the larger coefficients represent a more complete accounting of mortality effects, including both the cumulative total of short-term mortality as well as an additional chronic effect. This is, however, not the only possible interpretation of the disparity. Various reviewers have argued that (1) the long-term estimates may be biased high and/or (2) the short-term estimates may be biased low. In this view, the two study types could be measuring the same underlying relationship.

Reviewers have noted some possible sources of upward bias in the long-term studies. Some have noted that the less robust estimates based on the Six-Cities Study are significantly higher than those based on the more broadly distributed ACS data sets. Some reviewers have also noted that the observed mortality associations from the 1980s and 90s may reflect higher pollution exposures from the 1950s to 1960s. While this would bias estimates based on more recent pollution levels upwards, it also would imply a truly long-term chronic effect of pollution. With regard to possible sources of downward bias, it is of note that the recent studies suggest that the single day time series studies may understate the short-term effect on the order of a factor of two. These considerations provide a basis for considering an Alternative Estimate using the most recent estimates from the wealth of time-series studies, in addition to one based on the long-term cohort studies.

In essence, the Alternative Estimate addresses the above noted uncertainties about the relationship between premature mortality and long-term exposures to ambient levels of fine particles by assuming that there is no mortality effect of chronic exposures to fine particles. Instead, it assumes that the full impact of fine particles on premature mortality can be captured using a concentration-response function relating daily mortality to short-term fine particle levels. Specifically, a concentration-response function based on Schwartz et al. (1996) is employed, with an adjustment to account for recent evidence that daily mortality is associated with particle levels from a number of previous days (Schwartz, 2000), similar to the adjustment for the PM_{10} mortality C-R function described for the Base Estimate.

There are no $PM_{2.5}$ daily mortality studies which report numeric estimates of relative risks from distributed lag models; only PM_{10} studies are available. Daily mortality C-R functions for PM_{10} are consistently lower in magnitude than $PM_{2.5}$-mortality C-R functions, because fine particles are believed to be more closely associated with mortality than the coarse fraction of PM. Given that the NOx emissions reductions under the RICE NESHAP result primarily in reduced ambient concentrations of $PM_{2.5}$, use of a PM_{10} based C-R function results in a significant downward bias in the estimated reductions in mortality. To account for the full potential multi-day mortality impact of acute $PM_{2.5}$ events, we use the same adjustment factor (1.9784) used in developing the PM_{10} mortality C-R function, applied to the $PM_{2.5}$ based C-R function reported in Schwartz et al. (1996).

If most of the increase in mortality is expected to be associated with the fine fraction of PM_{10}, then it is reasonable to assume that the same proportional increase in risk would be observed if a distributed lag model were applied to the $PM_{2.5}$ data. There are two relevant coefficients from the Schwartz et al. (1996) study, one corresponding to all-cause mortality, and one corresponding to chronic obstructive pulmonary disease (COPD) mortality (separation by cause is necessary to implement the life years lost approach detailed below). The adjusted estimates for these two C-R functions are:

All cause mortality = 0.001489 * 1.9784 = 0.002946

COPD mortality = 0.003246 * 1.9784 = 0.006422

Note that these estimates, while approximating the full impact of daily pollution levels on daily death counts, do not capture any impacts of long-term exposure to air pollution. As discussed earlier, EPA's Science Advisory Board, while acknowledging the uncertainties in estimation of a PM-mortality relationship, has repeatedly recommended the use of a study that does reflect the impacts of long-term exposure. The omission of long-term impacts accounts for approximately 40 percent reduction in the estimate of avoided premature mortality in the Alternative Estimate relative to the Base Estimate.

8.3.3 *Valuing Individual Health Effect Endpoints*

The appropriate economic value of a change in a health effect depends on whether the health effect is viewed ex ante (before the effect has occurred) or ex post (after the effect has occurred). Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health affects by a fairly small amount for a large population. The appropriate economic measure is therefore ex ante WTP for changes in risk. However, epidemiological studies generally provide estimates of the relative risks of a particular health effect avoided due to a reduction in air pollution. A convenient way to use this data in a consistent framework is to convert probabilities to units of avoided statistical incidences. This measure is calculated by dividing individual WTP for a risk reduction by the related observed change in risk. For example, suppose a measure is able to reduce the risk of premature mortality from 2 in 10,000 to 1 in 10,000 (a reduction of 1 in 10,000). If individual WTP for this risk reduction is $100, then the WTP for an avoided statistical premature mortality amounts to $1 million ($100/0.0001 change in risk). Using this approach, the size of the affected population is automatically taken into account by the number of incidences predicted by epidemiological studies applied to the relevant population. The same type of calculation can produce values for statistical incidences of other health endpoints.

For some health effects, such as hospital admissions, WTP estimates are generally not available. In these cases, we use the cost of treating or mitigating the effect as a Base estimate.

For example, for the valuation of hospital admissions we use the avoided medical costs as an estimate of the value of avoiding the health effects causing the admission. These costs of illness (COI) estimates generally understate the true value of reductions in risk of a health effect. They tend to reflect the direct expenditures related to treatment but not the value of avoided pain and suffering from the health effect.

In the HDD RIA and TSD, we describe how the changes in health effects should be valued and indicate the value functions selected to provide monetized estimates of the value of changes in health effects. Table 8-3 below summarizes the value estimates per health effect that we used in this analysis. Note that the unit values for hospital admissions are the weighted averages of the ICD-9 code-specific values for the group of ICD-9 codes included in the hospital admission categories.

Adjustments for Growth in Real Income

Our analysis also accounts for expected growth in real income over time. Economic theory argues that WTP for most goods (such as environmental protection) will increase if real incomes increase. The economics literature suggests that the severity of a health effect is a primary determinant of the strength of the relationship between changes in real income and WTP (Alberini, 1997; Miller, 2000; Viscusi, 1993). As such, we use different factors to adjust the WTP for minor health effects, severe and chronic health effects, and premature mortality. Adjustment factors used to account for projected growth in real income from 1990 to 2005 are 1.03 for minor health effects, 1.09 for severe and chronic health effects, and 1.08 for premature mortality.[6]

[6]Details of the calculation of the income adjustment factors are provided in the HDD RIA (EPA, 2000d).

Table 8-3. Unit Values Used for Economic Valuation of Health Endpoints

Health or Welfare Endpoint	Estimated Value Per Incidence (1999$) Central Estimate	Derivation of Estimates
Premature Mortality (long-term exposure endpoint, Base Estimate)	$6 million per statistical life	Value is the mean of value-of-statistical-life estimates from 26 studies (5 contingent valuation and 21 labor market studies) reviewed for the Section 812 Costs and Benefits of the Clean Air Act, 1990-2010 (EPA, 1999).
Premature Mortality (short-term exposure endpoints, Alternative Estimate)	Varies by age and life years lost	See section on Valuation of Premature Mortality, Alternative Estimate, in text
Chronic Bronchitis (Base Estimate)	$331,000	Value is the mean of a generated distribution of WTP to avoid a case of pollution-related CB. WTP to avoid a case of pollution-related CB is derived by adjusting WTP (as described in Viscusi et al., 1991) to avoid a severe case of CB for the difference in severity and taking into account the elasticity of WTP with respect to severity of CB.
Chronic Bronchitis (Alternative Estimate)	$107,000	Cost of Illness (COI) estimate based on Cropper and Krupnick (1990).
Hospital Admissions		
All Ozone-Related Respiratory	$9,823	
Chronic Obstructive Pulmonary Disease (COPD) (ICD codes 490-492, 494-496)	$12,378	The COI estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Elixhauser (1993).
Pneumonia (ICD codes 480-487)	$14,693	The COI estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total pneumonia category illnesses) reported in Elixhauser (1993).
Asthma admissions	$6,634	The COI estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total asthma category illnesses) reported in Elixhauser (1993).
All Cardiovascular (ICD codes 390-429)	$18,387	The COI estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total cardiovascular illnesses) reported in Elixhauser (1993).
Emergency room visits for asthma	$299	COI estimate based on data reported by Smith, et al. (1997).

Health or Welfare Endpoint	Estimated Value Per Incidence (1999$) Central Estimate	Derivation of Estimates
Respiratory Ailments Not Requiring Hospitalization		
Any of 19 Acute Symptoms (ozone-related)	$22	
Upper Respiratory Symptoms (URS)	$24	Combinations of the 3 symptoms for which WTP estimates are available that closely match those listed by Pope, et al. result in 7 different "symptom clusters," each describing a "type" of URS. A dollar value was derived for each type of URS, using mid-range estimates of WTP (IEc, 1994) to avoid each symptom in the cluster and assuming additivity of WTPs. The dollar value for URS is the average of the dollar values for the 7 different types of URS.
Lower Respiratory Symptoms (LRS)	$15	Combinations of the 4 symptoms for which WTP estimates are available that closely match those listed by Schwartz, et al. result in 11 different "symptom clusters," each describing a "type" of LRS. A dollar value was derived for each type of LRS, using mid-range estimates of WTP (IEc, 1994) to avoid each symptom in the cluster and assuming additivity of WTPs. The dollar value for LRS is the average of the dollar values for the 11 different types of LRS.
Acute Bronchitis	$57	Average of low and high values recommended for use in Section 812 analysis (Neumann, et al., 1994)
Restricted Activity and Work Loss Days		
Decreased Worker Productivity	$1 per worker per 10% change in ozone	
Work Loss Days (WLDs)	Variable	Regionally adjusted median weekly wage for 1990 divided by 5 (adjusted to 1999$) (U.S. Bureau of the Census, 1992).
Minor Restricted Activity Days (MRADs)	$48	Median WTP estimate to avoid one MRAD from Tolley, et al. (1986) .

8.3.3.1 *Valuation of Reductions in Premature Mortality Risk*

Below we present the method for valuing premature mortality in our Base and Alternative Estimates. In both estimates, the values reflect two alternative discount rates, three percent and seven percent, used to estimate the present value of the effect. The choice of a discount rate, and its associated conceptual basis, is a topic of ongoing discussion within the federal government. We adopted a three percent discount rate to reflect reliance on a "social rate of time preference" discounting concept, which is recommended by EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b). We also calculate benefits using a seven percent rate consistent with an "opportunity cost of capital" concept to reflect the time value of resources directed to meet regulatory requirements, which is recommended by OMB Circular A-94 (OMB, 1992). In this analysis, the benefit estimates were not significantly affected by the choice of discount rate. Further discussion of this topic appears in EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b).

<u>Base Estimate</u>

The monetary benefit of reducing premature mortality risk was estimated using the "value of statistical lives saved" (VSL) approach, although the actual valuation is of small changes in mortality risk experienced by a large number of people. The VSL approach applies information from several published value-of-life studies, which themselves examine tradeoffs of monetary compensation for small additional mortality risks, to determine a reasonable benefit of preventing premature mortality. The mean value of avoiding one statistical death is estimated to be $6 million in 1999 dollars. This represents an intermediate value from a range of estimates that appear in the economics literature, and it is a value the EPA has used in rulemaking support analyses and in the Section 812 Reports to Congress.

This estimate is the mean of a distribution fitted to the estimates from 26 value-of-life studies identified in the Section 812 reports as "applicable to policy analysis." The approach and set of selected studies mirrors that of Viscusi (1992) (with the addition of two studies), and uses the same criteria as Viscusi in his review of value-of-life studies. The $6 million estimate is consistent with Viscusi's conclusion (updated to 1999$) that "most of the reasonable estimates of the value of life are clustered in the $3.7 to $8.6 million range." Five of the 26 studies are contingent valuation (CV) studies, which directly solicit WTP information from subjects; the rest are wage-risk studies, which base WTP estimates on estimates of the additional compensation demanded in the labor market for riskier jobs, controlling for other job and employee characteristics such as education and experience. As indicated in the previous section on quantification of premature mortality benefits, we assume for this analysis that some of the incidences of premature mortality related to PM exposures occur in a distributed fashion over the five years following exposure. To take this into account in the valuation of reductions in premature mortality, we apply an annual three percent discount rate to the value of premature mortality occurring in future years.

The economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still developing. The adoption of a value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economic and public policy analysis community. Regardless of the theoretical economic considerations, distinctions in the monetary value assigned to the lives saved were not drawn, even if populations differed in age, health status, socioeconomic status, gender or other characteristics.

Following the advice of the EEAC of the SAB, the VSL approach was used to calculate the Base Estimate of mortality benefits (EPA-SAB-EEAC-00-013). While there are several differences between the risk context implicit in labor market studies we use to derive a VSL estimate and the particulate matter air pollution context addressed here, those differences in the affected populations and the nature of the risks imply both upward and downward adjustments. For example, adjusting for age differences between subjects in the economic studies and those affected by air pollution may imply the need to adjust the $6 million VSL downward, but the involuntary nature of air pollution-related risks and the lower level of risk-aversion of the manual laborers in the labor market studies may imply the need for upward adjustments.

Some economists emphasize that the value of a statistical life is not a single number relevant for all situations. Indeed, the VSL estimate of $6 million (1999 dollars) is itself the central tendency of a number of estimates of the VSL for some rather narrowly defined populations. When there are significant differences between the population affected by a particular health risk and the populations used in the labor market studies, as is the case here, some economists prefer to adjust the VSL estimate to reflect those differences.

There is general agreement that the value to an individual of a reduction in mortality risk can vary based on several factors, including the age of the individual, the type of risk, the level of control the individual has over the risk, the individual's attitudes towards risk, and the health status of the individual. While the empirical basis for adjusting the $6 million VSL for many of these factors does not yet exist, a thorough discussion of these uncertainties is included in EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b). The EPA recognizes the need for investigation by the scientific community to develop additional empirical support for adjustments to VSL for the factors mentioned above.

As further support for the Base benefits estimate, the SAB-EEAC advised in their recent report that the EPA "continue to use a wage-risk-based VSL as its Base Estimate, including appropriate sensitivity analyses to reflect the uncertainty of these estimates," and that "the only risk characteristic for which adjustments to the VSL can be made is the timing of the risk"(EPA-SAB-EEAC-00-013). In developing the Base Estimate of the benefits of premature mortality reductions, we have discounted over the lag period between exposure and premature mortality. However, in accordance with the SAB advice, we use the VSL in the Base Estimate.

<u>Alternative Estimate</u>

The Alternative Estimate reflects the impact of changes to key assumptions associated with the valuation of mortality. These include: (1) the impact of using wage-risk and contingent valuation-based value of statistical life estimates in valuing risk reductions from air pollution as opposed to contingent valuation-based estimates alone, (2) the relationship between age and willingness-to-pay for fatal risk reductions, and (3) the degree of prematurity in mortalities from air pollution.

The Alternative Estimate addresses the first issue by using an estimate of the value of statistical life that is based only on the set of five contingent valuation studies included in the larger set of 26 studies recommended by Viscusi (1992) as applicable to policy analysis. The mean of the five contingent valuation based VSL estimates is $3.7 million (1999$), which is approximately 60 percent of the mean value of the full set of 26 studies.

The second issue is addressed by assuming that the relationship between age and willingness-to-pay for fatal risk reductions can be approximated using an adjustment factor derived from Jones-Lee (1989). The SAB has advised the EPA that the appropriate way to account for age differences is to obtain the values for risk reductions from the age groups affected by the risk reduction. Several studies have found a significant effect of age on the value of mortality risk reductions expressed by citizens in the United Kingdom (Jones-Lee et al., 1985; Jones-Lee, 1989; Jones-Lee, 1993).

Two of these studies provide the basis to form ratios of the WTP of different age cohorts to a base age cohort of 40 years. These ratios can be used to provide Alternative age-adjusted estimates of the value of avoided premature mortalities. One problem with both of the Jones-Lee studies is that they examine VSL for a limited age range. They then fit VSL as a function of age and extrapolate outside the range of the data to obtain ratios for the very old. Unfortunately, because VSL is specified as quadratic in age, extrapolation beyond the range of the data can lead to a very severe decline in VSL at ages beyond 75.

A simpler and potentially less biased approach is to simply apply a single age adjustment based on whether the individual was over or under 65 years of age at the time of death. This is consistent with the range of observed ages in the Jones-Lee studies and also agrees with the findings of more recent studies by Krupnick et al. (2000) that the only significant difference in WTP is between the over 70 and under 70 age groups. To correct for the potential extrapolation error for ages beyond 70, the adjustment factor is selected as the ratio of a 70 year old individual's WTP to a 40 year old individual's WTP, which is 0.63, based on the Jones-Lee (1989) results and 0.92 based on the Jones-Lee (1993) results. To show the maximum impact of the age adjustment, the Alternative Estimate is based on the Jones-Lee (1989) adjustment factor of 0.63, which yields a VSL of $2.3 million for populations over the age of 70. Deaths of individuals under the age of 70 are valued using the unadjusted mean VSL value of $3.7 million (1999$). Since these are acute mortalities, it is assumed that there is no lag between reduced exposure and reduced risk of mortality.

Jones-Lee and Krupnick may understate the effect of age because they only control for income and do not control for wealth. While there is no empirical evidence to support or reject hypotheses regarding wealth and observed WTP, WTP for additional life years by the elderly may in part reflect their wealth position *vis a vis* middle age respondents.

The third issue is addressed by assuming that deaths from chronic obstructive pulmonary disease (COPD) are advanced by 6 months, and deaths from all other causes are advanced by 5 years. These reductions in life years lost are applied regardless of the age at death. Actuarial evidence suggests that individuals with serious preexisting cardiovascular conditions have a remaining life expectancy of around 5 years. While many deaths from daily exposure to PM may occur in individuals with cardiovascular disease, studies have shown relationships between all cause mortality and PM, and between PM and mortality from pneumonia (Schwartz, 2000). In addition, recent studies have shown a relationship between PM and non-fatal heart attacks, which suggests that some of the deaths due to PM may be due to fatal heart attacks (Peters et al., 2001). And, a recent meta-analysis has shown little effect of age on the relative risk from PM exposure (Stieb et al., 2002), which suggests that the number of deaths in non-elderly populations (and thus the potential for greater loss of life years) may be significant. Indeed, this analysis estimates that 21 percent of non-COPD premature deaths avoided are in populations under 65. Thus, while the assumption of 5 years of life lost may be appropriate for a subset of total avoided premature mortalitites, it may over or underestimate the degree of life shortening attributable to PM for the remaining deaths.

In order to value the expected life years lost for COPD and non-COPD deaths, we need to construct estimates of the value of a statistical life year. The value of a life year varies based on the age at death, due to the differences in the base VSL between the 65 and older population and the under 65 population. The valuation approach used is a value of statistical life years (VSLY) approach, based on amortizing the base VSL for each age cohort. Previous applications have arrived at a single value per life year based on the discounted stream of values that correspond to the VSL for a 40 year old worker (EPA, 1999a). This assumes 35 years of life lost is the base value associated with the mean VSL value of $3.7 million (1999$). The VSLY associated with the $3.7 million VSL is $163,000, annualized assuming EPA's guideline value of a 3 percent discount rate, or $270,000, annualized assuming OMB's guideline value of a 7 percent discount rate. For example, using the 3 percent discount rate, the VSL applied in this analysis is then built up from that VSLY by taking the present value of the stream of life years. Thus, if you assume that a 40 year-old dying from pneumonia would lose 5 years of life, the VSL applied to that death would be $0.79 million. For populations over age 65, we then develop a VSLY from the age-adjusted base VSL of $2.3 million. Given an assumed remaining life expectancy of 10 years, this gives a VSLY of $258,000, assuming a 3 percent discount rate. A similar calculation is used to derive the VSLY estimate using a 7% discount rate. Again, the VSL is built based on the present value of 5 years of lost life, so in this case, we have a 70 year old individual dying from pneumonia losing 5 years of life, implying an estimated VSL of $1.25 million. As a final step, these estimated VSL values are multiplied by the appropriate adjustment factors to account for changes in WTP over time, as outlined above.

Applying the VSLY approach to the four categories of acute mortality results in four separate sets of values for an avoided premature mortality based on age and cause of death. Non-COPD deaths for populations aged 65 and older are valued at $1.4 million per incidence in 2010, and $1.6 million in 2020. Non-COPD deaths for populations aged 64 and younger are valued at $0.88 million per incidence in 2010, and $1.0 million in 2020. COPD deaths for populations aged 65 and older are valued at $0.15 million per incidence in 2010, and $0.17 million in 2020. Finally, COPD deaths for populations aged 64 and younger are valued at $0.096 million per incidence in 2010, and $0.11 million in 2020. The implied VSL for younger populations is less than that for older populations because the value per life year is higher for older populations. Since we assume that there is a 5 year loss in life years for a PM related mortality, regardless of the age of person dying, this necessarily leads to a lower VSL for younger populations.

Note that the NMMAPS study used to derive the C-R function for PM_{10} did not provide separate estimates for different causes of death, so we are unable to determine the proportion of PM_{10} deaths that are attributable to COPD or other causes. In the Base analysis, such distinctions are unnecessary, as all reductions in incidence of premature mortality are valued equally, regardless of age at death or remaining life expectancy. In the alternative estimate, the value of avoided incidences of premature mortality is determined by age and remaining life expectancy, so cause of death and age are important. Given the lack of data on cause of death, we assume all deaths from PM_{10} are equivalent (within an age category) and result in the same number of life years lost, assumed to be equal to 5 years.

8.3.3.2 *Valuation of Reductions in Chronic Bronchitis*

Base Estimate

The best available estimate of WTP to avoid a case of chronic bronchitis (CB) comes from Viscusi et al. (1991). The Viscusi et al. study, however, describes a severe case of CB to the survey respondents. We therefore employ an estimate of WTP to avoid a pollution-related case of CB, based on adjusting the Viscusi, et al. (1991) estimate of the WTP to avoid a severe case. This is done to account for the likelihood that an average case of pollution-related CB is not as severe. The adjustment is made by applying the elasticity of WTP with respect to severity reported in the Krupnick and Cropper (1992) study. Details of this adjustment procedure can be found in the Heavy-Duty Engine/Diesel Fuel RIA and its supporting documentation, and in the most recent Section 812 study (EPA, 1999).

We use the mean of a distribution of WTP estimates as the central tendency estimate of WTP to avoid a pollution-related case of CB in this analysis. The distribution incorporates uncertainty from three sources: (1) the WTP to avoid a case of severe CB, as described by Viscusi et al.; (2) the severity level of an average pollution-related case of CB (relative to that of the case described by Viscusi et al.); and (3) the elasticity of WTP with respect to severity of the illness. Based on assumptions about the distributions of each of these three uncertain components, we derive a distribution of WTP to avoid a pollution-related case of CB by statistical uncertainty analysis techniques. The expected value (i.e., mean) of this distribution, which is about $331,000 (1999$), is taken as the central tendency estimate of WTP to avoid a PM-related case of CB.

Alternative Estimate

For the Alternative Estimate, a cost-of illness value is used in place of willingness-to-pay to reflect uncertainty about the value of reductions in incidences of chronic bronchitis. In the Base Estimate, the willingness-to-pay estimate was derived from two contingent valuation studies (Viscusi et al., 1991; Krupnick and Cropper, 1992). These studies were experimental studies intended to examine new methodologies for eliciting values for morbidity endpoints. Although these studies were not specifically designed for policy analysis, the SAB (EPA-SAB-COUNCIL-ADV-00-002, 1999a) has indicated that the severity-adjusted values from this study provide reasonable estimates of the WTP for avoidance of chronic bronchitis. As with other contingent valuation studies, the reliability of the WTP estimates depends on the methods used to obtain the WTP values. In order to investigate the impact of using the CV based WTP estimates, the Alternative Estimate relies on a value for incidence of chronic bronchitis using a cost-of-illness estimate based on Cropper and Krupnick (1990) which calculates the present value of the lifetime expected costs associated with the illness. The current cost-of-illness (COI) estimate for chronic bronchitis is around \$107,000 per case, compared with the current WTP estimate of \$330,000.

8.3.4 *Methods for Describing Uncertainty*

In any complex analysis using estimated parameters and inputs from numerous models, there are likely to be many sources of uncertainty.[7] This analysis is no exception. As outlined both in this and preceding chapters, there are many inputs used to derive the final estimate of benefits, including emission inventories, air quality models (with their associated parameters and inputs), epidemiological estimates of concentration-response (C-R) functions, estimates of values (both from WTP and cost-of-illness studies), population estimates, income estimates, and estimates of the future state of the world (i.e., regulations, technology, and human behavior). Each of these inputs may be uncertain, and depending on their location in the benefits analysis, may have a disproportionately large impact on final estimates of total benefits. For example, emissions estimates are used in the first stage of the analysis. As such, any uncertainty in emissions estimates will be propagated through the entire analysis. When compounded with uncertainty in later stages, small uncertainties in emission levels can lead to much larger impacts on total benefits.

Some key sources of uncertainty in each stage of the benefits analysis are:

- Gaps in scientific data and inquiry;

[7]It should be recognized that in addition to uncertainty, the annual benefit estimates for the RICE NESHAP presented in this analysis are also inherently variable, due to the truly random processes that govern pollutant emissions and ambient air quality in a given year. Factors such as electricity demand and weather display constant variability regardless of our ability to accurately measure them. As such, the estimates of annual benefits should be viewed as representative of the types of benefits that will be realized, rather than the actual benefits that would occur every year.

- Variability in estimated relationships, such as C-R functions, introduced through differences in study design and statistical modeling;
- Errors in measurement and projection for variables such as population growth rates;
- Errors due to mis-specification of model structures, including the use of surrogate variables, such as using PM_{10} when $PM_{2.5}$ is not available, excluded variables, and simplification of complex functions; and
- Biases due to omissions or other research limitations.

Some of the key uncertainties in the benefits analysis are presented in Table 8-3. Information on the uncertainty surrounding particular C-R and valuation functions is provided in HDD TSD.

Our estimate of total benefits should be viewed as an approximate result because of the sources of uncertainty discussed above (see Table 8-4). The total benefits estimate may understate or overstate actual benefits of the rule.

In considering the monetized benefits estimates, the reader should remain aware of the many limitations of conducting these analyses mentioned throughout this RIA. One significant limitation of both the health and welfare benefits analyses is the inability to quantify many of the serious effects discussed in Chapter 7. For many health and welfare effects, such as PM-related materials damage, reliable C-R functions and/or valuation functions are not currently available. In general, if it were possible to monetize these benefits categories, the benefits estimates presented in this analysis would increase. Unquantified benefits are qualitatively discussed in the health and welfare effects sections of this RIA. The net effect of excluding benefit and disbenefit categories from the estimate of total benefits depends on the relative magnitude of the effects.

Table 8-4. Primary Sources of Uncertainty in the Source Benefit Analyses

1. Uncertainties Associated With Concentration-Response (C-R) Functions

- The value of the PM-coefficient in each C-R function. - Application of a single C-R function to pollutant changes and populations in all locations. - Similarity of future year C-R relationships to current C-R relationships. - Correct functional form of each C-R relationship. - Extrapolation of C-R relationships beyond the range of PM concentrations observed in the study. - Application of C-R relationships only to those subpopulations matching the original study population.
2. Uncertainties Associated With PM Concentrations
- Responsiveness of the models to changes in precursor emissions resulting from the control policy. - Projections of future levels of precursor emissions, especially ammonia and crustal materials. - Model chemistry for the formation of ambient nitrate concentrations.
3. Uncertainties Associated with PM Mortality Risk
- No scientific literature supporting a direct biological mechanism for observed epidemiological evidence. - Direct causal agents within the complex mixture of PM have not been identified. - The extent to which adverse health effects are associated with low level exposures that occur many times in the year versus peak exposures. - The extent to which effects reported in the long-term exposure studies are associated with historically higher levels of PM rather than the levels occurring during the period of study. - Reliability of the limited ambient $PM_{2.5}$ monitoring data in reflecting actual $PM_{2.5}$ exposures.
4. Uncertainties Associated With Possible Lagged Effects
- The portion of the PM-related long-term exposure mortality effects associated with changes in annual PM levels would occur in a single year is uncertain as well as the portion that might occur in subsequent years.
5. Uncertainties Associated With Baseline Incidence Rates
- Some baseline incidence rates are not location-specific (e.g., those taken from studies) and may therefore not accurately represent the actual location-specific rates. - Current baseline incidence rates may not approximate well baseline incidence rates in 2005. - Projected population and demographics may not represent well future-year population and demographics.
6. Uncertainties Associated With Economic Valuation
- Unit dollar values associated with health and welfare endpoints are only estimates of mean WTP and therefore have uncertainty surrounding them. - Mean WTP (in constant dollars) for each type of risk reduction may differ from current estimates due to differences in income or other factors.
7. Uncertainties Associated With Aggregation of Monetized Benefits
- Health and welfare benefits estimates are limited to the available C-R functions. Thus, unquantified or unmonetized benefits are not included.

8.4 DERIVATION OF BENEFIT TRANSFER VALUES FOR THE RICE NESHAP

8.4.1 *Ozone Benefit Transfer Values for Application to NOx Emission Reductions*

The ozone benefits analysis conducted for this RIA includes three categories of ozone related health benefits,[2] but not the ozone related welfare benefits (including changes in agricultural and forest productivity[3]). These categories are not included in this analysis due to a lack of suitable sources for benefit transfer. The agricultural and forestry models used to generate benefits are national sector models. As such, the outputs of these models are not suitable for disaggregation to dollar per ton values. Benefits from the omitted welfare categories (primarily commercial agriculture and forestry) accrue in rural areas, and thus may be important sources of benefits from reductions in emissions from RICE sources. This will lead to a downward bias in the reported estimates of benefits from NOx reductions.

The first step of the benefit transfer method is to select an existing air quality analysis from which to obtain changes in ambient ozone concentrations. Two factors guide the selection of an ozone air quality analysis for use in the RICE NESHAP benefits analysis: (1) while both NOx and VOC contribute to ozone formation, this regulation will lead to reductions predominately in NOx,[8] and 2) RICE sources are stationary combustion sources (as opposed to mobile sources such as vehicles). As such, an existing set of ozone air quality results covering primarily NOx reductions at stationary combustion sources is the most appropriate match.

We selected an air quality scenario developed for the NOx SIP call. This air quality scenario uses the Urban Airshed Model, version 5 (UAM-V) to predict ambient ozone concentration changes in 2007 from a 0.15 lb/mmBTU limit on NOx emissions for electric utilities and a 60 percent reduction in NOx emissions for non-utility point sources. UAM-V is a regional scale ozone model accounting for spatial and temporal variations as well as differences in the reactivity of emissions. Ozone air quality is modeled for the Ozone Transport Assessment Group (OTAG) region (essentially the 37 easternmost states). The model segments the area in the OTAG region into grids, each of which has several layers of ambient conditions that are considered in the analysis. Using this data, the UAM-V generates predictions of hourly ozone concentrations for every grid. Results of this process are used to generate ozone profiles at monitor sites by applying derived adjustment factors to the actual 1990 ozone data at each

[8]Some VOC reductions are expected from the controls applied to RICE sources. However, we are unable to measure them with a reasonable level of certainty. As the reductions are expected to be small, we do not anticipate a large impact on ambient ozone levels.

monitor site.[9] For areas without ozone monitoring data, ozone values are interpolated using data from monitors surrounding the area. For a more detailed discussion of UAM-V and the air quality interpolation procedure and the NOx SIP call reduction scenario, see the 1998 NOx SIP Call RIA and associated air quality technical support document (EPA, 1998; Abt Associates, 1998).

In prior EPA analyses (i.e., the 1997 Regulatory Impact Analysis (RIA) for the integrated pulp and paper rule and McKeever, 1997), we used air quality results with both NOx and VOC emission reductions. However, use of these results required the assumption of proportionality between emission reductions of VOCs and NOx and reductions in ambient ozone concentrations to obtain benefit transfer values for each pollutant. Subsequent to 1997, EPA has conducted air quality analyses of changes in ozone concentrations from NOx emissions alone. By using air quality results based solely on NOx emission reductions, all changes in ozone concentrations will be directly attributable to the NOx reductions, removing the need for assumptions about the proportion of changes in ambient ozone attributable to VOC reductions relative to NOx reductions.

To construct the dollar per ton ($/ton) benefit transfer value based on the NOx SIP call ozone benefits analysis estimate, we perform the following steps:

1) Adjust the ozone benefits estimated for the NOx SIP call to reflect the current set of endpoints and benefits assumptions and updated the base year to 1998 dollars.
2) Divide the resulting estimate by the total ozone season tons of NOx reduced under the NOx SIP call to obtain monetary ozone benefits per ton ($/ton) of NOx reduced.

[9]Ten decile adjustment factors are derived based on UAM-V modeled daytime hours (8:00 am–7:59 pm). From the distribution of these modeled hours, each decile is represented by its middle value. In other words, the first decile is represented by the 5th percentile value, the second decile by the 15th percentile value, and so on. For both the baseline and control scenarios, ten adjustment factors are then calculated using the ratio within each decile of the future year to the base year concentration. The ten adjustment factors for the baseline and control scenario are then used to adjust 1990 hourly ozone concentrations to projected 2007 concentrations. The lowest 10 percent of the distribution of these hours were multiplied by the first decile adjustment factor, the next 10 percent by the second adjustment factor and so on. Only daytime hours (8:00 am to 7:59 pm) were adjusted. Nighttime hours were assumed to be constant.

Step 1 is necessary due to the refinements in the benefits methodology that have occurred since the NOx SIP call analysis. The benefits analysis for the HDD RIA incorporates the latest guidance from the Science Advisory Board regarding appropriate endpoints for inclusion and appropriate valuation methods. For a complete description of the benefits methodology used to develop the HDD benefits estimates, see the HDD RIA and TSD. The key modification to the ozone benefits associated with NOx is that reductions in ozone-related mortality are no longer included in the primary estimate of ozone-related benefits.[10]

Step 2 converts total benefits into an appropriate dollar per ton metric using NOx emissions during the ozone season. Ozone season NOx reductions are the basis for the benefits reported for the NOx SIP call, reflecting the greater impact of NOx reductions on ozone formation during the ozone season (May through September). Note that annual RICE NOx reductions will also have to be separated into ozone and non-ozone season tons before application of the ozone $/ton transfer values. The calculations for this benefit transfer exercise are laid out in Table 8-5, and will be applied to emission reduction estimates for the RICE NESHAP.

[10]At least some evidence has been found linking both PM and ozone with premature mortality. The SAB has raised concerns that mortality-related benefits of air pollution reductions may be overstated if separate pollutant-specific estimates, some of which may have been obtained from models excluding the other pollutants, are aggregated. In addition, there may be important interactions between pollutants and their effect on mortality (EPA-SAB-Council-ADV-99-012, 1999b). The Pope et al. (1995) study used to quantify PM-related mortality included only PM, so it is unclear to what extent it may include the impacts of ozone or other gaseous pollutants. Because of concern about overstating of benefits and because the evidence associating mortality with exposure to particulate matter is currently stronger than for ozone, only the benefits of PM-related premature mortality avoided are included in the total benefits estimate.

Table 8-5. Ozone $/ton Transfer Values for NOx Reductions Using Estimates from the NOx SIP Call

	Description	Outcome (1998$)
Step 1a	Calculate unadjusted ozone-related health benefits from NOx SIP Call "Best Estimate" (Hubbell, 1998)	$1,690 million
Step 1b	Calculate adjusted ozone health benefits (applying SAB recommended current assumptions and endpoint sets[a])	$36 million
Step 2	Divide adjusted ozone benefits by total ozone season NOx reductions for the NOx SIP call	$36 million/1.3 million tons = $28/ton

[a] Includes hospital admissions for all respiratory causes, acute respiratory symptoms, and lost worker productivity.

8.4.2 *$PM_{2.5}$ Benefit Transfer Values for Application to NOx Emission Reductions*

$PM_{2.5}$ benefit transfer values associated with NOx reductions are developed using the same basic approach as for ozone. However, the specific air quality models and health endpoints differ. The $PM_{2.5}$ benefits analysis conducted for this RIA includes health benefits associated with reductions in both $PM_{2.5}$ and PM_{10}.[11] While Table 8-1 lists the endpoints included in this analysis, not all known health and welfare effects associated with PM are quantified and monetized for this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 8-13 later in this chapter. For more details on the sources and derivation of C-R functions and unit economic values for specific PM related health endpoints, see the HDD RIA and TSD.

The first step of the benefit transfer approach for $PM_{2.5}$ related to NOx reductions is to generate an emissions control scenario reflecting the types of reductions expected from the RICE NESHAP rule. Based on the NET96 emissions inventory, one-half of all NOx emissions from RICE sources totals 370,877 tons. In developing the RICE NESHAP we estimated NOx reductions to total 420,000 tons if all new sources (including major and area sources) were

[11] $PM_{2.5}$ is a fraction of PM_{10}. As such, reductions in NOx that lead to reductions in secondarily formed $PM_{2.5}$ will also be equivalent to reductions of PM_{10} in the same amount. Because $PM_{2.5}$ may be more strongly associated with health effects, we use $PM_{2.5}$ based concentration-response functions where available. However, due to limited availability of $PM_{2.5}$ data, many concentration-response functions are estimated using only PM_{10} data.

controlled. Thus during the development stage of the NESHAP, we concluded that an air quality analysis of approximately 50 percent reduction in NOx is reasonable to use to transfer results to the NESHAPs reductions. Thus, we selected and modeled a 50 percent reduction to NOx emissions from all RICE sources in the continental U.S. contained in the NET96 inventory. We recognize that many of the RICE sources included in the modeled air quality analysis will not be controlled under this NEHSAP, but this scenario provides a close approximation of the influence of NOx emissions reductions at RICE sources on concentrations of PM for the purpose of developing benefit transfer values.

PM air quality changes resulting from the 50 percent RICE NOx reduction were analyzed using a national-scale source-receptor matrix (S-R Matrix) based on the Climatological Regional Dispersion Model (CRDM) (Latimer and Associates, 1994; E.H. Pechan, 1994, 1996). Ambient concentrations of $PM_{2.5}$ are composed of directly emitted particles and of secondary aerosols of sulfate, nitrate, ammonium, and organics. Relative to more sophisticated and resource-intensive three-dimensional modeling approaches, the CRDM and its associated S-R Matrix do not fully account for all the complex chemical interactions that take place in the atmosphere in the secondary formation of PM. Instead it relies on more simplistic species dispersion–transport mechanisms supplemented with chemical conversion at the receptor location.

The S-R Matrix consists of fixed-coefficients that reflect the relationship between annual average PM concentration values at a single receptor in each county (i.e., a hypothetical monitor sited at the county population centroid) and the contribution by PM species to this concentration from each emission source (E.H. Pechan, 1997). The modeled receptors include all U.S. county centroids as well as receptors in 10 Canadian provinces and 29 Mexican cities/states. The methodology used in this RIA for estimating PM air quality concentrations is detailed in Pechan-Avanti (2000) and is similar to the method used in the RIA for the recent Tier 2/Gasoline Sulfur Rule (EPA, 1999e). For a complete description of the S-R Matrix, see chapter 7 of the Final Tier 2/Gasoline Sulfur RIA.

In the air quality modeling of the 50 percent NOx reduction scenario, results are based on a baseline 1996 emission inventory applied to populations estimated for the year 2005. The actual emissions in 2005 may be higher or lower than the 1996 baseline used in this analysis.

Given the changes in ambient $PM_{2.5}$ concentrations from the S-R matrix, the following are the key steps in the approach for developing a $PM_{2.5}$ benefit transfer value:

Step 1) Apply changes in $PM_{2.5}$ concentrations to selected health and welfare concentration-response functions at the population grid cell level[12].

Step 2) Apply valuation functions to the change in endpoint incidences and sum over endpoints to obtain monetary benefits at the population grid cell level.

Step 3) Sum monetary benefits over population grid cells to obtain aggregate monetary benefits estimates for the continental U.S.

Step 4) Divide aggregate monetary benefits by annual NOx emission reductions in the NET96 inventory to obtain a national $/ton estimate.

The calculations for this benefit transfer exercise are provided in Tables 8-6(a) and (b). Total reductions in NOx emissions for the 50 percent RICE NOx reduction scenario using the NET96 inventory are 370,877 tons. Dividing total benefits by the NOx emission reductions yields a $/ton estimate of $1,510 using the Base Estimate with a 3 percent discount rate on mortality, and $1,430 per ton using a 7 percent discount rate. Using results from the Alternative Estimate, the $/ton estimate using a 3 percent discount rate is $188, while using a 7 percent discount rate yields a $/ton of $215. Note that this averaging process implies that all reductions in emissions, wherever they occur, potentially affect air quality across the entire U.S. population. Thus, no additional scaling for population is appropriate.

[12]Changes in ambient pollutant concentrations are input to CAPMS, a custom benefits analysis program, to generate changes in health and welfare endpoints. CAPMS interpolates pollutant concentrations to population grid cells for input into concentration-response functions. CAPMS uses census block population data along with the interpolated changes in pollutant concentrations to estimate changes in endpoints at the population grid cell level. For more details on CAPMS, see the benefits technical support documents for the Final Tier 2/Gasoline Sulfur RIA. (Abt Associates, 1998b, 1999)

Table 8-6(a). Base Estimate of Annual Health Benefits Resulting from 50 Percent RICE NOx Emission Reduction Scenario[a]

Endpoint	Avoided Incidence[b] (cases/year)	Monetary Benefits, Adjusted for Growth in Income[c] (millions 1998$)
Premature mortality [d, e] (long-term exposure, adults, 30 and over):		
–Using a 3% discount rate	90	$535
–Using a 7% discount rate	90	$505
Chronic bronchitis (adults, 26 and over, WTP valuation)	60	$20
Hospital Admissions—Pnuemonia (adults, over 64)	10	$<1
Hospital Admissions—COPD (adults, 64 and over)	10	<$1
Hospital Admissions—Asthma (65 and younger)	10	<$1
Hospital Admissions—Cardiovascular (adults, over 64)	30	<$5
Emergency Room Visits for Asthma (65 and younger)	20	<$5
Asthma Attacks (asthmatics, all ages)	1,750	B_1
Acute Bronchitis (children, 8-12)	130	<$1
Lower Respiratory Symptoms (children, 7-12)	2,180	<$1
Upper Respiratory Symptoms (asthmatic children, 9-11)	2,150	<$1
Work loss days (adults, 18-65)	15,010	<$5
Minor restricted activity days (Adults, 18-65)	79,728	$5
Other NOx, PM, and HAP-related health effects[f]	U_1	B_2
Total PM Health-Related Benefits		
-Using a 3% discount rate[e]	—	\$560 + B_H
-Using a 7% discount rate[e]	—	\$530 + B_H

[a] The results presented in this table are based on a 50% reduction of all NOx emissions from RICE sources nationwide based on a 1996 emissions inventory (370,877 tons) evaluated with a 2005 population.

[b] Incidences are rounded to the nearest 10 and may not add due to rounding. Incidences of unquantified endpoints are indicated with a U.

[c] Dollar values are rounded to the nearest 5 million and may not add due to rounding.

[d] Note that the estimated value for PM-related premature mortality in the Base Estimate assumes the 5 year distributed lag structure described in detail in the Regulatory Impact Analysis of Heavy Duty Engine/Diesel Fuel rule.

[e] Results of premature mortality benefits reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).

[f] For notational purposes, unquantified benefits are indicated with a "U" to represent avoided incidences and a "B" to represent monetary benefits. A detailed listing of unquantified NOx, PM, and HAP related health effects is provided in Table 8-13.

Table 8-6(b). Alternative Estimate of Annual Health Benefits Resulting from 50 Percent RICE NOx Emission Reduction Scenario[a]

Endpoint	Avoided Incidence[b] (cases/year)	Monetary Benefits, Adjusted for Growth in Income[c] (millions 1998$)
Premature mortality [d, e] (short-term exposure):		
–Using a 3% discount rate	50	$55
–Using a 7% discount rate	50	$65
Chronic bronchitis (adults, 26 and over, COI valuation)	60	$5
Hospital Admissions—Pnuemonia (adults, over 64)	10	$<1
Hospital Admissions—COPD (adults, 64 and over)	10	<$1
Hospital Admissions—Asthma (65 and younger)	10	<$1
Hospital Admissions—Cardiovascular (adults, over 64)	30	<$5
Emergency Room Visits for Asthma (65 and younger)	20	<$5
Asthma Attacks (asthmatics, all ages)	1,750	B_1
Acute Bronchitis (children, 8-12)	130	<$1
Lower Respiratory Symptoms (children, 7-12)	2,180	<$1
Upper Respiratory Symptoms (asthmatic children, 9-11)	2,150	<$1
Work loss days (adults, 18-65)	15,010	<$5
Minor restricted activity days (Adults, 18-65)	79,730	$5
Other NOx, PM, and HAP-related health effects[f]	U_1	B_2
Total PM Health-Related Benefits[e]		
-Using a 3% discount rate	—	$70 + B_H
-Using a 7% discount rate	—	$80 + B_H

[a] The results presented in this table are based on a 50% reduction of all NOx emissions from RICE sources nationwide based on a 1996 emissions inventory (370,877 tons) evaluated with a 2005 population.
[b] Incidences are rounded to the nearest 10 and may not add due to rounding. Incidences of unquantified endpoints are indicated with a U.
[c] Dollar values are rounded to the nearest 5 million and may not add due to rounding.
[d] Note that the estimated value for PM-related premature mortality in the Base Estimate assumes the 5 year distributed lag structure described in detail in the Regulatory Impact Analysis of Heavy Duty Engine/Diesel Fuel rule.
[e] Results of premature mortality benefits reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).
[f] For notational purposes, unquantified benefits are indicated with a "U" to represent avoided incidneces and "B" to represent monetary benefits. A detailed listing of unquantified NOx, PM, and HAP related health effects is provided in Table 8-13.

Table 8-7. Benefit Value Per Ton of NOx—
Based on a 50% NOx Reduction at RICE Units[a]

	Benefit Per Ton of NOx Reduced
Base Estimate-	
Using 3% discount rate	\$1,510
Using 7% discount rate	\$1,430
Alternative Estimate-	
Using 3% discount rate	\$188
Using 7% discount rate	\$215

[a] Results reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).

8.4.3 *PM_{10} Benefit Transfer Values for Application to PM_{10} Emissions Reductions*

The RICE NESHAP is expected to reduce direct emissions of PM_{10}. Unlike the secondary formation of $PM_{2.5}$ that results from NOx reductions, direct PM_{10} emissions consist of all particles whose size are PM_{10} or smaller. In the prior section, $PM_{2.5}$ transfer values were developed to estimate benefits from reduced secondary formation of PM from NOx emissions. In this section, PM_{10} transfer functions are developed to value benefits of direct PM emission reductions, due to a lack of information on the fraction of PM_{10} from RICE that is $PM_{2.5}$.

Directly emitted PM_{10} benefit transfer values are developed using the same basic approach as for $PM_{2.5}$. However, the specific air quality scenario and health endpoints differ. The only difference in the transfer values for $PM_{2.5}$ and PM_{10} is the choice of mortality endpoint and the exclusion of health effects whose C-R functions are based on $PM_{2.5}$. While $PM_{2.5}$ is a component of PM_{10}, it is considered to potentially have a much larger impact on mortality due to long-term exposures. Given our inability to fractionate total PM_{10} into fine and coarse particles, we use the C-R function relating PM_{10} to premature mortality in developing the direct PM_{10} benefit transfer value in this section to avoid overstating potential impacts of reductions in total PM_{10}. Note again that not all known health and welfare effects associated with PM are quantified and monetized for this analysis. Potential benefit categories that have not been quantified and monetized are listed in 8-10 later in this chapter.

The first step of the benefit transfer approach for PM_{10} is to generate an air quality scenario reflecting the types of direct PM emissions reductions expected from the RICE NESHAP rule. We selected a scenario which modeled a 100 percent reduction in PM emissions from all RICE sources in the continental U.S. These emission reductions were then analyzed using the S-R matrix described above. While a 100 percent reduction in PM emissions at RICE sources does not reflect an approximation of the NESHAPs PM reductions, the 100 percent reduction scenario is necessary to observe results in the national scale air quality model. Because PM air quality impacts are linear in form, however, the results can be scaled to the NESHAPs level of control and is considered a representative benefit transfer value.

Following the same steps as used in generating the $PM_{2.5}$ transfer value for NOx reductions, the results of the benefit transfer development are presented in Table 8-8(a) and (b). Total reductions in direct PM emissions for the 100 percent RICE direct PM reduction scenario are 95,178 tons. Dividing total benefits by the PM emission reductions yields a $/ton estimate of $6,619 using the Base Estimate with a 3 percent discount rate, and $6,303 per ton with a 7 percent discount rate. Using the Alternative Estimate, the $/ton is $1,628 with a 3 percent discount rate and $1,681 with a 7 percent discount rate.

Table 8-8(a). Base Estimate: Annual Health Benefits Resulting from 100 Percent RICE Direct PM Emission Reduction Scenario[a]

Endpoint	Avoided Incidence[b] (cases/year)	Monetary Benefits, Adjusted for Growth in Income[c] (millions 1998$)
Premature mortality (short term exposure)[e] -Using a 3% discount rate	75	$465
-Using a 7% discount rate	75	$440
Chronic bronchitis (adults, 26 and over, WTP valuation)	440	$155
Hospital Admissions—Pnuemonia (adults, over 64)	100	<$5
Hospital Admissions—COPD (adults, 64 and over)	80	<$5
Hospital Admissions—Cardiovascular (adults, over 64)	240	$5
Emergency Room Visits for Asthma (65 and younger)	200	<$1
Asthma Attacks (asthmatics, all ages)	15,620	B_1
Lower Respiratory Symptoms (children, 7-12)	9,120	<$1
Upper Respiratory Symptoms (asthmatic children, 9-11)	16,730	<$1
Other NOX, PM, and HAP-related health effects[d]	U_1	B_2
Total PM Health-Related Benefits[e] -Using a 3% discount rate	—	$630 + B_H
-Using a 7% discount rate	—	$600 + B_H

[a] The results presented in this table are based on a 100% reduction of all direct PM emissions from RICE sources nationwide based on a 1996 emissions inventory (95,178 tons) evaluated with a 2005 population.
[b] Incidences are rounded to the nearest 10 and may not add due to rounding.
[c] Dollar values are rounded to the nearest 5 million and may not add due to rounding.
[d] For notational purposes, unquantified benefits are indicated with a "U" to represent avoided incidneces and "B" to represent monetary benefits. A detailed listing of unquantified NOx, PM, and HAP related health effects is provided in Table 8-13.
[e] Results of premature mortality benefits reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).

Table 8-8(b). Alternative Estimate: Annual Health Benefits Resulting from 100 Percent RICE Direct PM Emission Reduction Scenario[a]

Endpoint	Avoided Incidence[b] (cases/year)	Monetary Benefits, Adjusted for Growth in Income[c] (millions 1998$)
Premature mortality (short term exposure)[e]		
-Using a 3% discount rate	70	$95
-Using a 7% discount rate	70	$100
Chronic bronchitis (adults, 26 and over)	440	$50
Hospital Admissions—Pnuemonia (adults, over 64)	100	<$5
Hospital Admissions—COPD (adults, 64 and over)	80	<$5
Hospital Admissions—Cardiovascular (adults, over 64)	240	$5
Emergency Room Visits for Asthma (65 and younger)	200	<$1
Asthma Attacks (asthmatics, all ages)	15,620	B_1
Lower Respiratory Symptoms (children, 7-12)	9,120	<$1
Upper Respiratory Symptoms (asthmatic children, 9-11)	16,730	<$1
Other PM-related health effects[d]	U_1	B_2
Total PM Health-Related Benefits[e]		
-Using a 3% discount rate	—	\$155 + B_H
-Using a 7% discount rate	—	\$160 +B_H

[a] The results presented in this table are based on a 100% reduction of all direct PM emissions from RICE sources nationwide based on a 1996 emissions inventory (95,178 tons) evaluated with a 2005 population.
[b] Incidences are rounded to the nearest 10 and may not add due to rounding.
[c] Dollar values are rounded to the nearest 5 million and may not add due to rounding.
[d] For notational purposes, unquantified benefits are indicated with a "U" to represent avoided incidneces and "B" to represent monetary benefits. A detailed listing of unquantified NOx, PM , and HAP related health effects is provided in Table 8-13.
[e] Results of premature mortality benefits reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).

Table 8-9. Benefit Value Per Ton of PM_{10}— Based on a 100% Reduction of Direct PM_{10} at RICE Units

	Benefit Per Ton of PM_{10} Reduced
Base Estimate	
-Using a 3% discount rate	$6,619
-Using a 7% discount rate	$6,603
Alternative Estimate	
-Using a 3% discount rate	$1,628
-Using a 7% discount rate	$1,681

8.5 APPLICATION OF BENEFIT TRANSFER VALUES TO THE RICE NESHAP RULE

Using the ozone and PM benefit transfer values calculated above, we can develop an estimate of potential benefits associated with reductions in direct PM and NOx emissions at RICE sources. NOx emission reductions from the RICE NESHAP regulation are expected to be 167,900 tons per year at major sources once the regulation is fully implemented in 2005. Since no information is available about the distribution of these emission reductions across the year, we assume that emission reductions are equally distributed over all months. Thus, ozone season emissions (from May to September) will be approximately equal to 5/12 of annual emissions, or 70,000 tons. Because the NOx SIP call only estimated benefits for the reductions in NOx emissions in the easternmost 37 states, we must also apportion the emission reductions from the RICE NESHAP into eastern and western regions. Based on the 1996 NET emissions inventory, approximately 74 percent of NOx emissions from RICE facilities occurred in the eastern 37 states. Thus, we multiply NOx emission reductions by 0.74 to arrive at the 51,800 NOx tons to which the ozone benefit transfer value will be applied. For PM benefits, since we use a national model, total national emission reductions for the full year will be applied to the PM benefit transfer values (i.e., 167,900 tons NOx and 3,700 tons direct PM).

Using the equation for total benefits, the estimated monetary benefits of the NOx and PM reductions from the RICE NESHAP for the Base and Alternative Estimates are presented in Table 8-10.

Table 8-10. Benefits of the RICE NESHAP

	Reductions in Emissions (tons)			Benefit Transfer Values (1998$)			
				NOx		Direct PM	
	Ozone-season NOx[a]	Annual NOx	Annual Direct PM	Ozone	$PM_{2.5}$	PM_{10}	Total Monetized Benefits[b] (million 1998$)
Base Estimate[c]							
–Using 3% discount rate	51,800	167,900	3,700	$28	$1,510	$6,619	$280 + B
–Using 7% discount rate				$28	$1,430	$6,603	$265 + B
Alternative Estimate[c]							
–Using 3% discount rate	51,800	167,900	3,700	$28	$188	$1,628	$40 + B
–Using 7% discount rate				$28	$215	$1,681	$45 + B

[a] Emission reductions for ozone are for the Eastern United States, and are assumed to equal 5/12 of annual NOx reductions representing 5 months of the year associated with the ozone season.
[b] For notational purposes, unquantified benefits are indicated with a "B" to represent monetary benefits. A detailed listing of unquantified NOx, PM, and HAP related health effects is provided in Table 8-13.
[c] Results reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).

8.6 LIMITATIONS OF THE ANALYSIS

8.6.1 *Uncertainties and Assumptions*

Significant uncertainties and potential biases are inherent in any benefits analysis based on benefit transfer techniques. The degree of uncertainty and bias depends on how divergent the reality of the policy situation is from the state of the world assumed in the benefit transfer.

For this analysis, several key assumptions may lead to over or underestimation of benefits. Tables 8-11 and 8-12 list these assumptions, and where possible indicate the expected direction of the bias. This is by no means an exhaustive list, but captures what we have identified as key assumptions. In addition to these uncertainties and biases, there are uncertainties and biases embedded in the original benefits analyses from which the transfer values were generated. Some of these potential biases and assumptions are discussed in the preceding sections. For a full discussion of these uncertainties, see the NOx SIP Call RIA and the HDD RIA, as well as the Section 812 report to congress on the Benefits and Costs of the Clean Air Act 1990 to 2010.

Table 8-11. Significant Uncertainties and Biases in Derivation of the Benefit Transfer Values

Assumption	Direction of Bias
Impact of NOx reductions on PM formation is equivalent across all RICE sources	Unknown
Impact of NOx reductions on ozone formation is equivalent across all RICE sources	Unknown
Population distributions of PM and ozone reductions in source analyses are similar to population distributions of PM and ozone reductions resulting from the RICE NESHAP	Unknown
Benefits from source studies do not include all benefits and disbenefits	Unknown

8.6.2 *Unquantified Effects*

In addition to the monetized benefits presented in the above tables, it is important to recognize that many benefit categories associated with NOx and PM_{10} reductions are not quantified or monetized for this analysis. In addition to agricultural and forestry benefits, other potentially important unquantified benefit categories are listed in Table 8-13. For a more complete discussion of unquantified benefits and disbenefits, see the HDD RIA and the NOx SIP Call RIA.

Table 8-12. Significant Uncertainties and Biases in Application of Benefit Transfer Values to RICE NOx and PM Reductions

Assumption	Direction of Bias
Omission of commercial agriculture, forestry, visibility, and materials damage benefit categories	Downward
Same transfer value applied to all populations exposed to NOx and PM emissions from NESHAP sources	Unknown
Linear relationship between emission reductions and benefits	Upward
Meteorology in 2005 well-represented by modeled meteorology	Unknown

PM_{10} reductions are not quantified or monetized for this analysis. In addition to agricultural and forestry benefits, other potentially important unquantified benefit categories are listed in Table 8-13. For a more complete discussion of unquantified benefits and disbenefits, see the HDD RIA and the NOx SIP Call RIA.

Table 8-13. Unquantified Benefit Categories

	Unquantified Benefit Categories Associated with Ozone	Unquantified Benefit Categories Associated with PM
Health Categories	Airway responsiveness	Changes in pulmonary function
	Pulmonary inflammation	Morphological changes
	Increased susceptibility to respiratory infection	Altered host defense mechanisms
	Acute inflammation and respiratory cell damage	Cancer
	Chronic respiratory damage/Premature aging of lungs	Other chronic respiratory disease
	Emergency room visits for asthma	Emergency room visits for asthma
	Respiratory hospital admissions for children	Emergency room visits for non-asthma respiratory and cardiovascular causes
	Chronic asthma	Lower and upper respiratory symptoms
	Premature mortality (independent of PM related mortality)	Acute bronchitis
	Increased school absence rates	Shortness of breath
		Increased school absence rates
		Myocardial infarction (heart attacks)
Welfare Categories	Ecosystem and vegetation effects in Class I areas (e.g., national parks)	Materials damage
	Damage to urban ornamentals (e.g.,grass, flowers, shrubs, and trees in urban areas)	Damage to ecosystems (e.g., acid sulfate deposition)
	Commercial field crops	Nitrates in drinking water
	Fruit and vegetable crops	Visibility in recreational and residential areas
	Reduced yields of tree seedlings, commercial and non-commercial forests	
	Damage to ecosystems	
	Materials damage	

8.7 BENEFIT-COST COMPARISON

Benefit-cost analysis provides a valuable framework for organizing and evaluating information on the effects of environmental programs. When used properly, benefit-cost analysis helps illuminate important potential effects of alternative policies and helps set priorities for closing information gaps and reducing uncertainty. According to economic theory, the efficient policy alternative maximizes net benefits to society (i.e., social benefits minus social costs). However, not all relevant costs and benefits can be captured in any analysis. Executive Order 12866 clearly indicates that unquantifiable or nonmonetizable categories of both costs and benefits should not be ignored. There are many important unquantified and unmonetized costs and benefits associated with reductions in PM and NOx emissions, including many health and welfare effects. Potential PM and NOx benefit categories that have not been quantified and monetized are listed in Table 8-13 of this chapter. It is also important to recall that this analysis is only of the monetizable benefits associated with NOx and direct PM reductions. The rule is designed to reduce HAP emissions to a level mandated by the Clean Air Act - the MACT floor. It also achieves significant CO reductions. By achieving these emission reductions, the rule reduces the risks associated with exposures to those pollutants, including the toxic effects and risk of fatal cancers associated with HAPs, and the effects on the central nervous system and cardiovascular system associated with CO. The monetized benefit estimates presented in this chapter are thus expected to underestimate total benefits of the rule.

In addition to categories that cannot be included in the calculated net benefits, there are also practical limitations for the comparison of benefits to costs in this analysis, which have been discussed throughout this chapter. Several specific limitations deserve to be mentioned again here:

- The state of atmospheric modeling is not sufficiently advanced to provide a workable "one atmosphere" model capable of characterizing ground-level pollutant exposure for all pollutants of interest (e.g., ozone, particulate matter, carbon monoxide, nitrogen deposition, etc). Therefore, the EPA must employ several different pollutant models to characterize the effects of alternative policies on relevant pollutants. Also, not all atmospheric models have been widely validated against actual ambient data. Additionally, significant shortcomings exist in the data that are available to perform these analyses. While containing identifiable shortcomings and uncertainties, EPA believes the models and assumptions used in the analysis are reasonable based on the available evidence and resources.

C Qualitative and more detailed discussions of the above and other uncertainties and limitations are included in detail in earlier sections. Data limitations prevent an overall quantitative estimate of the uncertainty associated with final estimates. Nevertheless, the reader should keep all of these uncertainties and limitations in mind when reviewing and interpreting the results.

C The Base benefit estimate does not include the monetary value of several known ozone and PM-related welfare effects, including commercial forest growth, recreational and residential visibility, household soiling and materials damage, and deposition of nitrogen to sensitive estuaries.

- The benefit estimates presented in this document do not capture any additional short-term mortality impacts related to changes in exposure to ambient ozone. A recent analysis by Thurston and Ito (2001) reviewed previously published time series studies of the effect of daily ozone levels on daily mortality and found that previous EPA estimates of the short-term mortality benefits of the ozone NAAQS (EPA, 1997b) may have been underestimated by up to a factor of two. The authors hypothesized that much of the variability in published estimates of the ozone/mortality effect could be explained by how well each model controlled for the influence of weather, an important confounder of the ozone/mortality effect, and that earlier studies using less sophisticated approaches to controlling for weather consistently under-predicted the ozone/mortality effect. They found that models incorporating a non-linear temperature specification appropriate for the "U-shaped" nature of the temperature/mortality relationship (i.e., increased deaths at both very low and very high temperatures) produced ozone/mortality effect estimates that were both more strongly positive (a two percent increase in relative risk over the pooled estimate for all studies evaluated) and consistently statistically significant. Further accounting for the interaction effects between temperature and relative humidity produced even more strongly positive results. Inclusion of a PM index to control for PM/mortality effects had little effect on these results, suggesting an ozone/mortality relationship independent of that for PM. However, most of the studies examined by Ito and Thurston only controlled for PM_{10} or broader measures of particles and did not directly control for $PM_{2.5}$. As such, there may still be potential for confounding of $PM_{2.5}$ and ozone mortality effects, as ozone and $PM_{2.5}$ are highly correlated during summer months in some areas[13]. In its September 2001 advisory on the draft analytical blueprint for the second Section 812 prospective analysis, the SAB cited the Thurston and Ito study as a significant advance in understanding the effects of ozone on daily mortality and recommended re-evaluation of the ozone mortality endpoint for inclusion in the next prospective study (EPA-SAB-COUNCIL-ADV-01-004, 2001). Thus, recent evidence suggests that by not including an estimate of reductions in short-term mortality due to changes in ambient ozone, both the Base and Alternative Estimates may underestimate the benefits of implementation of the RICE NESHAP.

Nonetheless, if one is mindful of these limitations, the relative magnitude of the benefit-cost comparison presented here can be useful information. Thus, this section summarizes the benefit and cost estimates that are potentially useful for evaluating the efficiency of the RICE NESHAP rulemaking.

The estimated social cost of implementing the RICE program is approximately $255 million (1998$) in the fifth year, while the estimate of NOx and PM-related monetized benefits are $280 + B million (3 percent discount rate), or 265 + B million (7 percent discount rate) under

[13] Short-term ozone mortality risk estimates may also be affected by the statistical issue discovered by the Health Effects Institute (Greenbaum, 2002a). See page 24 for a more detailed discussion of this issue.

the Base Estimate. Under the Alternative Estimate, total benefits are \$40 + B million (3 percent discount rate), or \$45 + B million (7 percent discount rate). Comparison with costs indicates that the monetized benefits of NOx and PM reductions exceed costs by approximately \$25 + B million (3 percent discount rate), or \$15 million + B (7 percent discount rate) under the Base Estimate. Under the Alternative Estimate, net benefits are –\$215 + B million (3 percent discount rate), or –\$210 + B million (7 percent discount rate). Note that while monetized benefits of PM and NOx reductions exceed monetized costs only under our Base Estimate, PM and NOx benefits account for only a portion of the benefits of this rule. Again, with the omission of a quantified value for any of the benefits of HAPs and CO reductions, total net benefits of the rule are understated.

With respect to the benefits of reducing exposure to HAPs, EPA has developed a rudimentary risk analysis focusing only on cancer risks. As discussed above, this analysis suggests that the proposed rule would reduce cancer incidence by roughly 10 cases per year if it were implemented at all affected RICE facilities. Placing a value on these impacts would increase the economic benefits of the rule. This analysis carries significant assumptions, uncertainties, and limitations. EPA is working with the SAB to develop better methods for analyzing the cancer and non-cancer benefits of HAP reductions. EPA will include a monetized estimate of the benefits of reducing HAP emissions with the analysis for the final rule if it is able to develop better methods before promulgation of this rule.

It is also important to note that not only are entire pollutant categories missing from our benefit estimate, but also not all benefits of PM and NOx reductions have been monetized. Categories which have contributed significantly to monetized benefits in past analyses (see the NOx SIP call and HDD RIAs) include increased productivity of commercial agriculture and forestry, improved recreational and residential visibility, and reductions in deposition to nitrogen sensitive estuaries. Table 8-13 lists known unquantified benefits associated with PM and NOx reductions. Thus, this information should be used in conjunction with information provided in all other chapters of this report to understand the overall impacts of the rule on society. Table 8-14 and 8-15 summarizes the costs, benefits, and net benefits for the MACT Floor regulatory option.

Additionally, we did not attempt to estimate welfare benefits associated with ozone and PM reductions for this rule because of the difficulty in developing reliable benefit transfer values for these effects. The SAB has recently reviewed existing studies valuing improvements in residential visibility and reductions in household soiling and advised that these studies do not provide an adequate basis for valuing these effects in cost-benefit analyses (EPA-SAB-COUNCIL-ADV-00-002, 1999; EPA-SAB-COUNCIL-ADV-003, 1999a). Reliable methods do exist for valuing visibility improvements in Federal Class I areas, however, the benefit transfer method outlined above does not allow for predictions of changes in visibility at specific Class I areas. These predictions are necessary to estimate Class I area visibility benefits. As such we have left this potentially important endpoint unquantified for this analysis. Given the proximity of some RICE sources to national parks in the west and northwest, these omitted benefits may be significant.

Table 8-14. Summary of Costs, Emission Reductions, and Quantifiable Benefits by Engine Type

Type of Engine	Total Annualized Cost (million $/yr in 2005)	Emission Reductions[a] (tons/yr in 2005)				Quantifiable Annual Monetized Benefits[b, c] (million $/yr in 2005)	
		HAP	CO	NOx	PM	Base Estimate	Alternative Estimate
2SLB–New	$3	250	2,025	0	0	B_1	B_2
4SLB–New	$66	4,035	36,240	0	0	B_3	B_4
4SRB–Existing	$38	230	98,040	69,900	0	$105 + B_5 $100 + B_6	$15 + B_7 $15 + B_8
4SRB–New	$48	215	91,820	98,000	0	$150 + B_9 $140 + B_{10}	$20 + B_{11} $25 + B_{12}
CI–New	$99	305	6,320	0	3,700	$25 + B_{13}	$5 + B_{14}
Total	$255	5,035	234,445	167,900	3,700	$280 + B $265 + B	$40 + B $45 + B

[a] For the calculation of PM-related benefits, total NOx reductions are multiplied by the appropriate benefit per ton value presented in Table 8-7. For the calculation of ozone-related benefits, NOx reductions are multiplied by 5/12 to account for ozone season months and 0.74 to account for Eastern States in the ozone analysis. The resulting ozone-related NOx reductions are multiplied by $28 per ton. Ozone-related benefits are summed together with PM-related benefits to derive total benefits of NOx reductions. All benefits values are rounded to the nearest $5 million.

[b] Benefits of HAP and CO emission reductions are not quantified in this analysis and, therefore, are not presented in this table. The quantifiable benefits are from emission reductions of NOx and PM only. For notational purposes, unquantified benefits are indicated with a "B" to represent monetary benefits. A detailed listing of unquantified NOx, PM, and HAP related health effects is provided in Table 8-13.

[c] Results reflect the use of two different discount rates; a 3% rate which is recommended by EPA's Guidelines for Preparing Economic Analyses (EPA, 2000b), and 7% which is recommended by OMB Circular A-94 (OMB, 1992).

Table 8-15. Annual Net Benefits of the RICE NESHAP in 2005

	Million 1998$[a]
Social Costs[b]	$255
Social Benefits[b, c, d]:	
HAP-related benefits	Not monetized
CO-related benefits	Not monetized
Ozone- and PM-related Welfare benefits	Not monetized
Ozone- and PM-related Health benefits:	
Base Estimate	
–Using 3% Discount Rate	$280 + B
–Using 7% Discount Rate	$265 + B
Alternative Estimate	
–Using 3% Discount Rate	$40 + B
–Using 7% Discount Rate	$45 + B
Net Benefits (Benefits - Costs)[c, d]:	
Base Estimate	
–Using 3% Discount Rate	$25 + B
–Using 7% Discount Rate	$10 + B
Alternative Estimate	
–Using 3% Discount Rate	–$215 + B
–Using 7% Discount Rate	–$210 + B

[a] All costs and benefits are rounded to the nearest $5 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier sections of the chapter.

[b] Note that costs are the total costs of reducing all pollutants, including HAPs and CO, as well as NOx and PM_{10}. Benefits in this table are associated only with PM and NOx reductions.

[c] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table 8-13. B is the sum of all unquantified benefits and disbenefits.

[d] Monetized benefits are presented using two different discount rates. Results calculated using 3 percent discount rate are recommended by EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b). Results calculated using 7 percent discount rate are recommended by OMB Circular A-94 (OMB, 1992).

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APPENDICES

APPENDIX A:
ECONOMIC MODEL OF MARKETS AFFECTED BY THE RICE MACT

Implementation of the proposed MACT standards will affect the costs of production in U.S. energy markets, thus changing the amount of energy that producers are willing to supply and leading to a change in price. Because energy is used as an input in the production of most goods and services, changes in the price of energy will affect almost all of the markets in the U.S. to some extent. Specifically, the cost of the regulation may cause individual facilities to decrease their current level of production or even to close. These choices affect, and in turn are affected by, the market price for each product. As the individual facilities in a market decrease their current level of production, the market supply will decrease as well.

The Agency developed an economic model of markets affected by the proposed rule to estimate its economic impact (see Section 5 for details on the conceptual approach). In addition to the impact on the energy markets, many final product markets where RICE units are used as part of the production process will also be affected. The economic analysis employs standard concepts in microeconomics to model the regulation's impacts on production costs, supply, equilibrium price and quantity, and economic welfare. This appendix presents the structural equations used in the computer model to estimate these impacts and discusses the method used for welfare calculations.

A.1 ENERGY MARKETS MODEL

The operational model includes four energy markets: coal, electricity, natural gas, and petroleum. The following sections describe supply and demand equations the Agency developed to characterize these markets. The data source for the price and quantity data used to calibrate the model is the Department of Energy's Supplemental Tables to the Annual Energy Outlook 2000 (EIA, 2000c).

A.1.1 *Supply Side Modeling*

The Agency modeled the existing market supply of energy markets (Q_{Si}) using a single representative supplier with an upward-sloping supply curve. The Cobb-Douglas (CD) function specification is

$$Q_{S_i} = A_i \bullet (p_i - c_i - \sum_{j=1}^{n} \alpha_j \Delta p_j)^{\varepsilon^{s_i}} \qquad \text{(A.1)}$$

where

Q_{S_i}	=	the supply of energy product i,
A_i	=	a parameter that calibrates the supply equation to replicate the estimated 2005 level of production (Btu),
p_i	=	the projected 2005 ($/Btu) market price for product i,
c_i	=	per-unit direct compliance costs generated by dividing the annual control costs estimated by the engineering analysis by the production level (Q_{S_i}),
ε^{S_i}	=	the domestic supply elasticity for product i, and
$\sum_{j=1}^{n} \alpha_j \Delta p_j$	=	indirect effect of changes in energy input prices, where "$_j$ is the fuel share of energy product j used in producing energy product i. The fuel share is allowed to vary using a fuel switching rule relying on cross-price elasticities of demand between energy sources, as described in Section 5 of the report.

A.1.2 *Demand Side Modeling*

Market demand in the energy markets (Q_{Di}) is expressed as the sum of the energy, residential, transportation, industrial, and commercial sectors:

$$Q_{Di} = \sum_{j=1}^{n} q_{Dij} \, , \qquad \text{(A.2)}$$

where i indexes the energy market and j indexes the consuming sector. The Agency modeled the residential, and transportation sectors as single representative demanders using a simple Cobb Douglas specification:

$$q_{Dij} = A_{ij} p_i^{\eta_{ij}} , \tag{A.3}$$

where p is the market price, 0 is an assumed demand elasticity (actual values are presented in Section 5, Table 5-2), and A is a demand parameter used to calibrate the demand equations to match baseline conditions.

In contrast, energy demand in the energy, industrial and commercial sectors is modeled as a derived demand resulting from the production/consumption choices in the agricultural, energy, mining, manufacturing, and service industries. Energy demand for these industries responds to changes in output as well as fuel switching that occurs in response to changes in relative energy prices projected in the energy markets. For each sector, energy demand is expressed as follows:

$$q_{Dij1} = (1 + \%\Delta Q_{Dj}) \cdot (q_{Dij0}) \cdot FSW \tag{A.4}$$

where q_D is demand for energy, Q_D is output in the final product or service market, FSW is a factor generated by the fuel switching algorithm, i indexes the energy market, j indexes the market. The subscripts 0 and 1 represent baseline and with regulation conditions, respectively.

A.2 INDUSTRIAL AND COMMERCIAL MARKETS

Given data limitations associated with the scope of potentially affected industrial and commercial markets, EPA used an alternative approach to estimate the relative changes in price and quantities in these markets. Rather than using measures of price and quantity as in the energy markets, data for the industrial and commercial markets was estimated in terms of percentage changes in prices and quantities relative to baseline values. The estimated percentage changes in prices and quantities in each market are used to compute changes in economic welfare as described in Section A.4.

A.2.1 *Compute Percentage Change in Market Price*

First, we computed the change in production costs resulting from changes in the market price of fuels (determined in the energy markets):

$$\%\Delta c_j = \sum_{i=1}^{n} \alpha_i \Delta p_i \ , \tag{A.5}$$

where " is the fuel share,[1] i indexes the energy market, and j indexes the industrial or commercial market. We use the results from equation A.5 and the market supply and demand elasticities to compute the percentage change in market price[2]:

$$\%\Delta p_j = \%\Delta c_j \cdot \left[\frac{\varepsilon^{s_i}}{\varepsilon^{s_i} - \eta_i} \right] \tag{A.6}$$

A.2.2 *Compute Percentage Change in Market Quantity*

Using the percentage change in the price calculated in Equation A.6 and assumptions regarding the market demand elasticity, the relative change in quantity was computed. For example, in a market where the demand elasticity is assumed to be –1 (i.e., unitary), a 1 percent increase in price results in a 1 percent decrease in quantity. This change was then input into equation A.4 to determine energy demand.

A.3 WITH-REGULATION MARKET EQUILIBRIUM DETERMINATION

Market adjustments can be conceptualized as an interactive feedback process. Supply segments face increased production costs as a result of the rule and are willing to supply smaller quantities at the baseline price. This reduction in market supply leads to an increase in the market price that all producers and consumers face, which leads to further responses by producers and consumers and thus new market prices, and so on. The new with-regulation

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[1]The fuel share is allowed to vary using a fuel switching rule using cross-price elasticities of demand between energy sources, as described in Section 5.

[2]The approach is based on a mathematical model of tax incidence analysis decribed in Nicholson (1998) pages 444-445.

equilibrium is the result of a series of iterations in which price is adjusted and producers and consumers respond, until a set of stable market prices arises where total market supply equals market demand (i.e., $Q_S = Q_D$) in each market. Market price adjustment takes place based on a price revision rule that adjusts price upward (downward) by a given percentage in response to excess demand (excess supply).

The algorithm for determining with-regulation equilibria can be summarized by seven recursive steps:

1. Impose the control costs on electricity supply segments, thereby affecting their supply decisions.
2. Recalculate the market supply in the energy markets. Excess demand exists.
3. Determine the new energy prices via a price revision rule.
4. Recalculate energy market supply.
5. Account for fuel switching given new energy prices. Solve for new equilibrium in final product and service market.
6. Compute energy demand.
7. Compare supply and demand in energy markets. If equilibrium conditions are not satisfied, go to Step 3, resulting in a new set of energy prices. Repeat until equilibrium conditions are satisfied (i.e., the ratio of supply to demand is arbitrarily close to one).

A.4 COMPUTING SOCIAL COSTS

In the energy markets, consumer (residential and transportation sectors) and producer surplus were calculated using standard methods based on the price and quantity before and after regulation. In the industrial and commercial markets, however, there is no easily defined price or quantity due to the wide variety of products that fall under each sector (i.e., NAICS code). Therefore, methods of calculating consumer and producer surplus are defined based on relative changes in prices and quantities and total industry sales rather than on the prices and quantities directly. The following sections describe how we derive welfare estimates for these markets.

A.4.1 *Change in Consumer Surplus*

If price and quantities were available, a linear approximation of the change in consumer surplus can be calculated using the following formula:

$$\Delta CS = -[(\Delta P)\,Q_1 - 0.5(\Delta Q)\,(\Delta P)], \qquad (A.7)$$

where Q_1 denotes the estimated post-regulation quantity, ΔP denotes the estimated change in price resulting from the regulation, and ΔQ denotes the estimated change in quantity resulting from the regulation. Given the difficulties associated with defining baseline measures of price and quantity for broad NAICS codes described above, the model estimates relative changes in price and quantity for each industrial/commercial market. Thus, changes in consumer surplus were calculated using these data and total revenue by NAICS code as shown below:

$$\Delta CS = -[(\Delta P)\,Q_1 - 0.5\,(\Delta Q)\,(\Delta P)]\,(P_1\,Q_1)/(P_1\,Q_1)$$

$$\Delta CS = -[\%\Delta P - 0.5\;(\%\Delta P)\,(\%\Delta Q)]\,(P_1\,Q_1). \qquad (A.8)$$

A.4.2 *Change in Producer Surplus*

If price and quantities were available, a linear approximation could also be used to compute the change in producer surplus:

$$\Delta PS = -[((CC/Q_1) - \Delta P)(Q_1 - \Delta Q)] + 0.5\,[(CC/Q_1 - \Delta P)\,(\Delta Q)], \qquad (A.9)$$

where CC/Q_1 equals the per-unit "cost-shifter" of the regulation. Again, we transform this equation into one that relies only on percentage changes in price and quantity, total revenue,[3] and compliance costs:

$$\Delta PS = -\,[((CC/Q_1) - \Delta P)(Q_1 - \Delta Q)] + 0.5\,[((CC/Q_1) - \Delta P)(\Delta Q)](P_1\,Q_1)/(P_1\,Q_1)$$

$$\Delta PS = -\,[(\%\text{ cost shift} - \%\Delta P)(1 - \%\Delta Q) + 0.5\,(\%\text{ cost shift} - \%\Delta P\,)(\%\Delta Q)][P_1\,Q_1]$$

$$\Delta PS = -\,[\%\text{ cost shift} - \%\Delta P\,][1 - 0.5(\%\Delta Q)][TR], \qquad (A.10)$$

where TR refers to total revenue, which is equal to price multiplied by quantity. This modified formula no longer requires price and quantity directly[4] and can be applied to the final product markets where this information is not available.

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[3]Multiplying price and quantity in an industry yields total industry revenue. The U.S. Census Bureau provides shipment data for the NAICs codes included in the economic model.

[4]Only the product of price and quantity is required for this formula. Multiplying price and quantity in an industry yields total industry revenue. The value used for total industry revenue is derived from industry-level value of shipments data so that price and quantity do not have to be individually defined.

APPENDIX B:
ECONOMIC MODEL SENSITIVITY ANALYSIS

Estimates of the economic impacts of the MACT standard are sensitive to the parameters used in the model. Therefore, a sensitivity analysis was conducted to determine the effects on the model results of changing several of the key parameters. Sensitivity analyses were developed for the elasticity of supply in the electricity markets, the demand and supply elasticities in the manufacturing final product markets, the own- and cross-price elasticities used to model fuel switching, and the distribution of affected engines in SIC 13 between the natural gas and petroleum industries. In general, estimates of the change in social welfare are robust. The distribution of welfare losses across producers and consumers responds moderately to changes in the selected parameters.

B.1 ELASTICITY OF SUPPLY FOR ELECTRICITY

The price elasticity of supply in the electricity markets represents the behavioral responses from existing sources to changes in the price of electricity. However, there is no consensus on estimates of the price elasticity of supply for electricity, as discussed in Section 4 of the report. Because of deregulation, the market price for electricity has become the determining factor in decisions to retire older units or to make higher cost units available to the market, so the price elasticity of supply is becoming more important to utilities' decisionmaking. To examine how the assumed value of the elasticity of supply for electricity affects the model's outcomes, welfare impacts were estimated for supply elasticities both higher and lower than the assumed value of 0.75. Table B-1 shows the economic impact estimates as the elasticity of supply in the electricity markets is varied between 0.5 and 1.0.

Table B-1. Sensitivity Analysis: Elasticity of Supply in the Electricity Markets ($$10^6$)

	ES = 0.5	ES = 0.75	ES = 1.0
Change in producer surplus	–121.7	–122.1	–122.2
Change in consumer surplus	–125.8	–125.4	–125.4
Change in social welfare	–247.6	–247.6	–247.6

B.2 FINAL PRODUCT MARKET ELASTICITIES

The final product markets were modeled at the two- or three-digit NAICS code level to operationalize the economic model. Due to a lack of data on final product supply elasticities, the elasticity of supply was assumed to equal 0.75 in each of the final product markets. The elasticity of demand in each final product market was assumed to equal the values in Table 5-4. The elasticities of supply and demand in the final product markets determine the distribution of economic impacts between producers and consumers. To examine the change in distribution of welfare impacts as the elasticities are changed, two alternative assumptions about the elasticities in the final product markets were used. In the first alternative, supply is assumed to be 25 percent more inelastic than in the model, while the demand elasticity estimate remains the same. In the second alternative, the supply elasticity is the same as used in the model, but demand is assumed to be 25 percent more inelastic. Table B-2 shows how the economic impact estimates vary as the supply and demand elasticities in the final product markets vary. As expected, when supply becomes more inelastic, producers bear a larger share of the costs relative to the model results and when demand becomes more inelastic, it is the consumers who bear a larger share of the cost burden.

B.3 OWN AND CROSS-PRICE ELASTICITIES FOR FUELS

Own- and cross-price elasticities of demand from NEMS were used to capture fuel switching in the manufacturing sectors in the economic model. However, the NEMS projection reflects aggregate behavioral responses in the year 2015. Because this is a longer window of analysis compared to the baseline year 2005, this analysis may overestimate firms' ability to switch fuels in the short run.

Table B-2. Sensitivity Analysis: Supply and Demand Elasticities in the Industrial and Commercial Markets ($\$10^6$)

	Supply Elasticities Reduced by 25%	Base Case	Demand Elasticities Reduced by 25%
Change in producer surplus	–131.3	–122.1	–111.0
Change in consumer surplus	–116.3	–125.4	–136.5
Change in social welfare	–247.6	–247.6	–247.6

Table B-3 shows how the economic impact estimates vary as the own- and cross-price elasticities used in the economic analysis are reduced by 75 percent and 50 percent. Changing the elasticities used to model fuel switching has only a very small effect on the estimates of welfare changes.

Table B-3. Sensitivity Analysis: Own- and Cross-Price Elasticities Used to Model Fuel Switching ($\$10^6$)

	Fuel Price Elasticities Presented in Table 4-2	Reduced by 75 Percent	Reduced by 50 Percent
Change in producer surplus	–122.1	–124.3	–123.9
Change in consumer surplus	–125.4	–123.3	–123.6
Change in social welfare	–247.6	–247.6	–247.6

B.4 SHARE OF NAICS 211 ASSOCIATED WITH NATURAL GAS AND PETROLEUM PRODUCTS

Direct costs associated with the regulation are linked to the energy markets in which engines are operating. Because no information was available on each unit’s application, NAICS codes were used to link engines to specific energy markets. However, for NAICS 211 it was not possible to distinguish between engines involved in the extraction and production of natural gas and engines involved in the extraction and processing of petroleum products. In addition, because petroleum and natural gas are frequently joint products, some engines may be involved in both markets.

Based on information from industry, it was determined that the majority of the engines classified under NAICS 211 were involved in natural gas extraction and transportation. The economic impact estimates presented in Section 5 use an 80/20 percent distribution of control costs between the natural gas and petroleum markets. Table B-4 shows how the economic impact estimates vary as the 80/20 percent distribution of control costs between the natural gas and petroleum markets varies. Once again, there is only a slight difference in the distribution of costs between producers and consumers under this sensitivity analysis.

Table B-4. Sensitivity Analysis: Distribution of Affected Units in NAICS 211 Between the Natural Gas and Petroleum Industries ($\$10^6$)

	Natural Gas = 70% Petroleum = 30%	Natural Gas = 80% Petroleum = 20%	Natural Gas = 90% Petroleum = 10%
Change in producer surplus	–121.1	–122.1	–122.6
Change in consumer surplus	–126.4	–125.4	–124.9
Change in social welfare	–247.6	–247.6	–247.6

APPENDIX C:
ASSUMPTIONS AND LIMITATIONS OF THE ECONOMIC MODEL

In developing the economic model of effects of the RICE NESHAP, several assumptions were necessary to make the model operational. These assumptions are in addition to those described in Section 5.2 for the values of supply and demand elasticities. In this section, the major operational assumptions are listed and explained. Possible impacts and limitations of the model resulting from each assumption are then described.

Assumption: The domestic markets for energy are perfectly competitive.

Explanation: Assuming that the markets for energy are perfectly competitive implies that individual producers are not capable of unilaterally affecting the prices they receive for their products. Under perfect competition, firms that raise their price above the competitive price are unable to sell at that higher price because they are a small share of the market and consumers can easily buy from one of a multitude of other firms that are selling at the competitive price level. Given the relatively homogeneous nature of individual energy products (petroleum, coal, natural gas, electricity), the assumption of perfect competition at the national level seems to be appropriate.

Possible Impact: If energy markets were in fact imperfectly competitive, implying that individual producers can exercise market power and thus affect the prices they receive for their products, then the economic model would understate possible increases in the price of energy due to the regulation as well as the social costs of the regulation. Under imperfect competition, energy producers would be able to pass along more of the costs of the regulation to consumers; thus, consumer surplus losses would be greater, and producer surplus losses would be smaller in the energy markets.

Assumption: The domestic markets for industrial products are all perfectly competitive.

Explanation*:* Assuming that these markets are perfectly competitive implies that the producers of these products are unable to unilaterally affect the prices they receive for their products. Because the industries used in this analysis are aggregated across a large number of individual producers, it is a reasonable assumption that the individual producers have a very small share of industry sales and cannot individually influence the price of output from that industry.

Possible Impact: If these product markets were in fact imperfectly competitive, implying that individual producers can exercise market power and thus affect the prices they receive for their products, then the economic model would understate possible increases in the price of final products due to the regulation as well as the social costs of the regulation. Under imperfect competition, producers would be able to pass along more of the costs of the regulation to consumers; thus, consumer surplus losses would be greater, and producer surplus losses would be smaller in the final product markets.

Assumption: The baseline year of the analysis, 2005, provides representative information about the impacts on affected industries after new engines subject to the regulation have been installed.

Explanation: The engineering costs of the regulation are estimated for all engines projected to exist in 2005 in terms of 1998 dollars. For the economic model to be consistent, all costs and prices must be denominated in the same year. However, to examine future impacts, the number of engines projected to exist in 2005 is used in conjunction with costs and prices in 1998 dollars. Because most of the impact of the regulation is borne by new engines, it is more informative to use a future year that includes some of these new engines rather than the current year. In the current year, no new engines would be subject to the proposed rule. Choosing a baseline year 5 years into the future allows an examination of intermediate-run costs resulting from the regulation.

Possible Impact: If the projections for growth in the number of engines of each type (4SRB, 2SLB, 4SLB, CI) turn out to be incorrect, then the actual costs of the regulation will differ from the estimated values. Also, it is assumed that the relationships between many variables stay the same in 2005 as they are in 1998, the year that most of the data are from. For example, it is assumed that fuel costs remain the same proportion of production costs in 2005 as in 1998. If these relationships change over time, then the actual cost of the regulation in 2005 will differ from the estimated values. Also, because the number of engines subject to the regulation is projected to increase over time, the farther into the future the analysis looks, the higher the costs will be given the current projections. However, extrapolating far into the future may not give an accurate picture of the number of engines that will be used because many factors could change the growth rate of RICE.

Assumption: Fuel costs are a constant proportion of production costs.

Explanation: It is assumed that the percentage of production costs spent on fuels remains constant as the price of fuel changes. Because the price changes obtained in the model are so small, it is not unreasonable to assume that producers will not change the mix of inputs that they use in the production process as a result of the price increase.

Possible Impact: Theoretically, producers could switch their production process to one that requires less fuel by substituting more labor, capital, etc., for fuel. If producers respond to the increase in fuel prices by significantly altering their input mix and using less fuel, then the price in the energy markets will increase less than the estimated value due to the decrease in demand, and prices in the final product markets will also increase less than expected. In this case, producers will face higher welfare losses and consumers smaller welfare losses than in the current model.

Assumption: The amount of fuel required to produce a unit of output in the final product markets remains constant as output changes.

Explanation: The importance of this assumption is that when output in the final product markets changes as a result of a change in energy prices, it is assumed that the amount of fuel used changes in the same proportion as output, although the distribution of fuel usage among fuel types may change due to fuel switching. This change in the demand for fuels feeds into the energy markets and affects the equilibrium price and quantity in the energy markets.

Possible Impact: Fuel usage may not actually change in exactly this way. If fuel usage decreases more than proportionately, then the demand for fuels will decrease more, and there will be more downward pressure on energy prices than the model results suggest. If fuel usage decreases less than proportionately, then the demand for fuels will decrease less, and the price will be higher than the model result.

Assumption: All pipelines are affected by the regulation.

Explanation: It is assumed that new engines will be distributed across all existing pipelines and any new pipelines so that the cost of distribution rises for all natural gas rather than only affecting some producers and leaving others unaffected.

Possible Impact: If only some natural gas producers are affected and others are unaffected, then the unaffected firms may see their profits rise if the market price increases due to decreases in output from affected suppliers because the unaffected firms experience no shift in their cost curves as a result of the regulation. The relative proportion of affected and unaffected producers would then be important in determining the overall change in equilibrium price and quantity. If the regulation affected only a very small percentage of the market, then market price and quantity may not change appreciably.

APPENDIX D:
SUMMARY OF STUDIES OF THE EFFECTS OF EMISSIONS OF HAZARDOUS AIR POLLUTANTS

Although we are unable to quantify the effects of the HAPs reduced by this rule, below we present a qualitative discussion of the toxic effects of the pollutants that are controlled by the regulation. The information presented is obtained from the EPA's Integrated Risk Information System (IRIS) (EPA, 2002a; 2002b), which is a resource of health assessment information on chemical substances that have undergone a comprehensive review by EPA health scientists from several Program Offices and the Office of Research and Development. The summaries presented are the result of consensus reached during the review process. While this rule produces significant reductions in formaldehyde, acetaldehyde, acrolein, methanol, carbon monoxide, and nitrous oxides, IRIS based risk assessments due to inhalation are only available for formaldehyde and acetaldehyde.

Formaldehyde:

Based on a review of human epidemiological studies and available animal studies of the chronic effects from this pollutant, formaldehyde is classified as a "probable human carcinogen" if inhaled through the air (EPA, 2002b). The human data is "limited,"[1] but includes nine studies that show statistically significant associations between site-specific respiratory *neoplasms* and exposure to formaldehyde. Long-term inhalation studies in rats and mice are determined to be "sufficient"[2] and show an increased incidence of cancerous cells in the nasal cavity.

At least 28 epidemiological studies of the effects on humans have been conducted, nine of which are used for the classification of formaldehyde as a probable human carcinogen. Among these, two cohort studies (Blair et al., 1986, 1987; Stayner et al., 1988) and one case-

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[1]In general, "limited" means that the studies show a tendency for these effects, but the data used or study findings are limited to a small set of studies on humans or have a large amount of uncertainty associated with them.

[2]In general, "sufficient" means that there are a sufficient number of studies with statistically significant findings such that classification of carcinogenicity is more certain.

control study (Vaughan et al., 1996a, b) were well conducted according to IRIS and specifically designed to detect small to moderate increases in formaldehyde-associated human risks. Blair et al. studied workers at 10 plants who were in some way exposed to formaldehyde and observed significant excesses in lung and nasopharyngeal cancer deaths. Despite the lack of significant trends with increasing concentration or cumulative formaldehyde exposure, lung cancer mortality was significantly elevated in analyses with or without a 20-year latency allowance. Stayner et al. reported statistically significant excesses in mortality from buccal cavity tumors among formaldehyde-exposed garment workers. The case-control study conducted by Vaughan et al. examined occupational and residential exposures, and showed a significant association between nasopharyngeal cancer and having lived 10 or more years in a mobile home, especially for mobile homes built in the 1950's to 1970's, a period of increasing formaldehyde-resin usage.

The 25 other reviewed studies had limited ability to detect small to moderate increases in formaldehyde risks owing to small sample sizes, small numbers of observed site-specific deaths, and insufficient follow-up. Even with these potential limitations, 6 of the 25 studies reported significant associations between excess site-specific respiratory (lung, buccal cavity, and pharyngeal) cancers and exposure to formaldehyde. Although the common exposure in all of these studies was formaldehyde, the epidemiological evidence is categorized as "limited" in the IRIS database primarily because of the possible exposures to other agents. Such exposures could have contributed to the findings of excess cancers.

The data on animal carcinogenicity, however, was found to be sufficient. Consequences of inhalation exposure to formaldehyde have been studied in rats, mice, hamsters, and monkeys. Kerns et al. (1983) exposed about 120 mice and rats to 0, 2, 5.6, or 14.3 ppm, 6 hours/day, 5 days/week for 24 months. From the 12th month on, the rats in the highest dose group (14.3 ppm) showed significantly increased mortality compared to control groups. In the 5.6 ppm group, male rats showed a significant increase in mortality from 17 months on. Squamous cell carcinomas were seen in the nasal cavities of 51 out of 117 male rats and 52 out of 117 female rats at 14.3 ppm by experiment's end.

Tobe et al. (1985) conducted a 28-month study of male rats. Exposure to 15 ppm ended at 24 months; at that point, mortality was 88 percent. Squamous cell carcinomas were seen at 15 ppm in 14 out of 27 rats surviving past 12 months, compared with 0 out of 27 rats in the control group.

Based on the results of these studies, IRIS reports quantitative estimates of risk from inhalation exposure. One form in which risk is presented is an estimate of "unit risk." The unit risk is the quantitative estimate in terms of risk per ug/cu.m air breathed. Another form in which risk is presented is an air concentration providing cancer risks of 1 in 10,000, 1 in 100,000, and 1 in 1,000,000. The rationale and methods used to develop the carcinogenicity information in IRIS are described in The Risk Assessment Guidelines of 1986 (EPA/600/8-87/045) and in the IRIS Background Document available on the EPA's website. Using these guidelines, IRIS reports an inhalation unit risk for formaldehyde of 1.3E-5 (ug/cu.m), with a corresponding chance of cancer of 1 in 10,000 at concentrations of 8E+0 ug/cu.m, a 1 in 100,000 chance of cancer at concentrations of 8E-1 ug/cu.m, and a 1 in 1,000,000 chance of cancer at concentrations of 8E-2 ug/cu.m.

Acetaldehyde:

Acetaldehyde is similar in structure to formaldehyde which also produces nasal tumors in animals exposed to inhalation. When inhaled, acetaldehyde causes cancers in the nose and trachea of hamsters, and nasal cancers in rats. The epidemiological studies in humans is determined to be "inadequate,"[3] however, based on the evidence in animal studies (which are determined to be sufficient), acetaldehyde is classified as a probable human carcinogen (EPA, 2002a). Two short-term animal studies conducted by the same research group (Appleman et al., 1986; Appleman et al., 1982) are the principal studies used in the determination if a Reference Concentration (RfC) presented in IRIS. The RfC is a benchmark concentration at which risk is not a public health concern. If the RfC is exceeded, the risk of effects increases to an unsafe level. While these studies are short-term in duration, together they establish a concentration-response for lesions after only 4 weeks of exposure. These same types of lesions appear at longer exposure times and higher exposure levels in chronic studies (Wouterson et al., 1986; Wouterson and Feron, 1987; Kruysse et al., 1975).

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[3] In general, "inadequate" means that the there are too small a number of human studies to determine the classification, or the findings of the studies have a large level of uncertainty.

Appleman et al. (1986) conducted two inhalation studies on male rats. Continuous and interrupted *(define)* exposure to 500 ppm did not induce any visible effect on general condition or behavior, but peak exposures at this level caused irritation. Mean body weights of the group exposed to 500 ppm with interruption and with peak exposures were statistically significantly lower than those in the control group. *Histopathological* changes attributable to exposure were found only in the nasal cavity. Degeneration of the olfactory epithelium was observed in rats exposed to 500 ppm. Interruption of the exposure or interruption combined with peak exposure did not visibly influence this adverse effect.

The Appleman et al. (1982) study found that during the first 30 minutes of each exposure at the 5000-ppm level, rats exhibited severe *dyspnea* that gradually became less severe during the subsequent exposure period. Two animals died at this level and one male died at the 2200-ppm level. Growth was retarded in males at the three highest exposure concentrations (1000, 2200, and 5000 ppm) and in females at the 5000-ppm level. Compound-related histopathological changes were observed only in the respiratory system. The nasal cavity was most severely affected and exhibited a concentration-response function. At the 400-ppm level, compound-related change included: slight to severe degeneration of the nasal olfactory epithelium, without *hyper- and metaplasia, and disarragement* of epithelial cells. At the 1000- and 2200-ppm levels, more severe degenerative changes occurred, which *hyperplastice and metaplactis* changes in the olfactory and respiratory epithelium of the nasal cavity. Degenerations with hyperpolasia/metaplasia also occurred in the *laryngeal and tracheal epithelium* at these levels. At 5000 ppm changes included severe *degenerativehyperplastic and metplastic* changes of the nasal, laryngeal, and tracheal epithelium.

Wouterson et al.(1986) exposed rats for 6 hours/day, 5 days/week for up to 28 months to 0, 750, 1500 and 3000 ppm. The highest concentration was gradually decreased because of severe growth retardation, occasional loss of body weights, and early mortality in this group. The rats in this high concentration group showed excessive salivation, labored respiration, and mouth breathing. The respiratory distress was still observed when the concentration was reduced to 1000 ppm, although fewer were *dyspneic.* Only a few rats died during the first 6 months of the study but thereafter a sharp increase in the numbers of deaths occurred in the high-concentration group. By 25 months, all top concentration rats had died. When the study was terminated, only a few animals remained alive in the mid-concentration group. The cause of early death was nearly always partial or complete occlusion of the nose by excessive amounts of keratin and inflammatory exudate. Several showed acute bronchophnuemonia occasionally accompanied by tracheitis. The only exposure-related histopathology occurred in the respiratory system and showed a concentration-response relationship. The most severe abnormalities were found in the nasal cavity. Adenocarcinomas occurred at all exposure concentrations and squamous cell carcinoma at the mid and high concentrations only.

Data on animal carcinogenicity was determined to be sufficient and data from 3 studies is presented in IRIS. Feron (1979) exposed hamsters to 0 or 1500 ppm acetaldehyde by inhalation 7 hours/day, 5 days/weeks, for 52 weeks. The exposure produced twice the incidence of squamous cell carcinomas compared to the control group. Feron et al. (1982) found similar observations that support Feron (1979). In a study of hamsters exposed to acetaldehyde alone or in combination with benzo(a)pyrene (BaP), the animals showed a slight increase in nasal tumors and a significantly increased incidence of larygeal tumors. Woutersen and Appelman (1984) studied albino rats for 27 months and found multiple respiratory tract tumores. Adenocarcinomas were increased significantly at all exposure levels, and squamous cell carcinoma incidences showed a clear dose-response relationship.

The critical effect reported in IRIS for acetaldehyde is degenerations of olfactory epithelium and the inhalation Reference Concentration (RfC) is reported as 9E-3 mg/cu.m. In general, the RfC is an estimate of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Thus, if this concentration is exceeded on a daily basis, then degeneration of olfactory epithelium is likely to occur in humans. Similar to the formaldehyde description above, IRIS also presents risk of cancer in other terms. IRIS reports the inhalation unit risk for acetaldehyde as 2.2E-6 per ug/cu.m., with a corresponding risk of cancer of 1 in 10,000 at concentrations of 5E+1 ug/cu.m, a 1 in 100,000 risk of cancer at concentrations of 5E+0 ug/cu.m, and a 1 in 1,000,000 risk of cancer at concentrations of 5E-1 ug/cu.m.

TECHNICAL REPORT DATA

(Please read Instructions on reverse before completing)

1. REPORT NO. EPA-452/R-02-012	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Regulatory Impact Analysis for the Proposed Reciprocating Internal Combustion Engines NESHAP		5. REPORT DATE November 2002
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. None
12. SPONSORING AGENCY NAME AND ADDRESS Steve Page, Director Office of Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Proposed regulation
		14. SPONSORING AGENCY CODE EPA/200/04
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This report summarizes the benefits, costs, and economic impacts associated with the National Emissions Standard for Hazardous Air Pollutants (NESHAP) for the Reciprocating Internal Combustion Engines (RICE) source category. This source category includes spark ignition engines that operate generally with natural gas and compression ignition engines that operate with diesel fuel, and can be classified as two-stroke, or four-stroke engines. They are also classified by the richness of the fuel mix: rich burn or lean burn. RICE units are typically used along natural gas pipelines to provide adequate pressure to transmit fuel through the pipeline. Others are also used to provide power in a remote area of an operation in industries such as health services, energy generation, oil and gas extraction, and quarrying of non-metallic minerals.

In the 5th year after implementation, the proposed NESHAP for RICE will impact existing and new engine and is expected to reduce HAP emissions by 5,000 tons per year, 234,400 tons of carbon monoxide (CO) per year, 167,900 tons of nitrogen oxides (NOx) per year, and 3,700 tons of particulate matter (PM_{10}) per year. The total social cost of rule is approximately $255 million (1998$). This cost is spread across more than 25 different industries, which results in small economic impacts with minimal changes in prices and production levels in most affected industries. Benefits of the HAP reductions include reduced respiratory illnesses and reduced incidence of cancer, however, we are unable to quantify these effects. Benefits from NOx and PM reductions include fewer fatalities, and reduced incidence of chronic bronchitis, asthma, and other respiratory illnesses, which are valued at approximately $280 million per year.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Regulatory Impact Analysis Health Assessment Economic Analysis	air pollution control, environmental regulation, economic impact analysis, benefits, costs, maximum achievable control technology, reciprocating internal combustion engines	
18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(Report)* Unclassified	21. NO. OF PAGES 115
	20. SECURITY CLASS *(Page)* Unclassified	22. PRICE

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